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東京オリンピック選手強化対策本部
体育とスポーツNo. 31 (Vol.7 No.2)

再びスポーツと政治と

ＩＯＣ理事会は去る２月８日（於ローザンヌ）「スポーツへの政治介入防止に関する憲章草案」を発表し，その上いくつかの事実について具体的に理事会の態度を明らかにした．これはバロンデッセのようなものだが，これから国際競技連盟や各国ＮＯＣの意見を調整し，次いで今秋のナイロビＩＯＣ総会で最終決定に持ちこまれることになった．憲章草案は７項目の勧告を行なっているが，ＩＯＣとしては「政治とスポーツ」について基本的態度を明らかにし，スポーツの精神的基調を世界的広がりの中で固める必要に迫られたようである．

さて，最近スポーツに対する政治介入が目立って多くなってきた．身近かなところでは昨夏のアジア大会でのインドネシア政府がある．ポーランド（スキー），米国（重量挙，レスリング，アイスホッケー），西ドイツ（カヌー），フィリピン（バスケットボール）の政府も世界選手権や欧州選手権に特定国選手の入国を拒んだ．こうして政治的にスポーツの平和を阻んだ国は西側にも東側にもあり，また先進国にも未開発国にもあったが，このまま進めばやがて“目には目”で報復手段が講ぜられる．そして，国際競技開催の危うくなるのは日を見るよりも明らかである．ここらあたりで反省を促がし，スポーツの哲学を再認識させる必要があったと思われる．それはとにかく理想と現実の戦いは今後長期にわたって続くものと思われる．

しかし，世界の若ものはこの種の厄介な問題がうまく処理され，１年半後には“オリンピックの平和”の鐘の音を聞きつつ力いっぱい戦いたいと望んでいる．

この時われわれは過去のいくつかの事実の中から歴史の教訓を思い起こそう．

- 1500年も地下にうずまっていたオリンピック競技が現代に復活したのは，その底流にヒューマニズムの理想が流れているためであった．
- クーベルタンは，時の権威（政治）に屈せず理想主義を貫き通したが，そのお陰で近代オリンピックはいまもなお生存している．
- オリンピックを資本主義の遺産であると非難し参加を拒否していたソ連が，スターリン批判を契機として，急に態度を変えオリンピックの理想をたたえて1952年の大会から参加してきた．
- 東西ドイツはオリンピックに限って「統一ドイツ」で参加してくる．南北両鮮の場合も理想が政治（人為的なもの）を教導しようとしている．

時の政治とは時代的なもので変転する．そして時々発作を起こすものである．歴史は，それによって人間永遠の理想の炎がかき消されないことを教えている．

それにつけてもインドネシアの名スプリンター，サレンガト選手のことを思い出す．100m と高障害に優勝したあと同選手は“この次は東京でお目にかかりたい．そして世界の選手と力を競いたい”とその願いを述べた．その目は輝いて期待で胸がいっぱいの表情であった．このスポーツマンの心は世界の若者たちの心に結びついているが，この純情でひた向きの工業大学々生の前にいまあすを知れぬ政治の壁ができたのである．

ムード・ムード

昨年まで盛り上がらなかったムードが動いてきた．いままで盛り上がらなかったことも日本的であるが，起こりつつあるムードも特有の風土的性格を帯びているように思われる．起こっていることは起こらぬことよりも数倍よいが，しかし，これが選手強化の現場にどんな影響をもつかにかなり高い関心が払われよう．

われわれの期待するところは，現場のコーチと選手が環境のどんな変化にもめげず，かねての計画を計画通り忠実に誠意をこめて遂行することである．ムードは結構だが，現場がそれに惑わされたり，混乱に追いこまれては堪ったものではない．日本にいままで生まれなかった高い次元の選手を作る仕事，選手になる仕事は，創作に励む芸術家の仕事と同じであろう．知性と経験で立てた計画を愛情と誠実さで実行するその奥に実行を支えて推し進める心，目的に向う不退転のしかも冷静な決意がなくてはならない．

東京大会の成否にはムードはいささかの責任もとるまい．責任はもっぱらコーチと選手の側にあるのである．

東京オリンピック選手強化対策本部
副本部長　大島　鎌吉

病床の小泉信三先生からのメッセージ

3月16，17の両日の順天堂大学において昭和38年春季第1回コーチ会議が開催されたが，2日目の午後1時から行なわれる予定の小泉信三先生の特別講演“オリンピック東京大会にそなえる選手の心がまえ”が先生の突然の発病で止むなく中止されることとなった．しかしながら病床の小泉先生から以下のようなメッセージが贈られ，参会者全員，深い感動をもってその朗読に耳を傾けた．

御　挨　拶

今日は皆さんにお目にかかり，1つには皆さんの御苦労を謝し，1つには国民の1人として来たるべきオリンピックにおけるわが選手の健闘を祈る心を皆さんに伝えたいと思っていましたところ，昨夜突然発病し，今ベッドに横たわっていますので，甚だ失礼ながらまた遺憾ながら感ずるところの一端を紙に書いてお贈りし，朗読していただくことにしたいと思います．

よく勝敗は問題でないといいますが，それは事実ではありません．日本国民は日本の選手の勝利を祈っています．少なくも人に示して誇り得るような健闘を祈っています．

勝利への途は何か．ただ練習であります．ただ練習が不可能を可能にし，練習が奇蹟を行ないます．過去において誇るべき成績を上げた偉大なるわがスポーツマンはみな非常な努力者でありました．天才とは異常なる努力をなし得るものをいうとの事ですが，その意味において彼らは天才でありました．

50余年前，日本海々戦において敵バルチック艦隊主力の全部を撃沈し，捕獲して完全「撃滅」をなし遂げたわが司令長官，東郷平八郎は，100発100中の砲1門は，100発1中の砲100門に敵すると称し，自ら日々鎮海湾の現場に赴いて至厳至烈の訓練を励ましたのでありました．そうしてその結果があの完全撃滅となったのであります．この事はわれわれ日本のスポーツマンに多くを教えると思います．

日本海々戦の完全戦勝はアジア諸国民に対する強い刺激となりました．今日アジア民族主義とか反植民地主義とかいう名の下に，アジア諸国民の西欧強国に対するまき返しが行なわれていますが，遠くその原因に遡ってそれを求めれば，日本海々戦の圧勝はたしかにその1つであり，こうしてその圧勝はわが将兵の猛訓練の賜ものであったとすれば，練習は世界の歴史を動かすというも不可なしといえるのではないでしょうか．

わが指導者諸君の御苦労は一方ならぬものであることを推察しますが，私は諸君がバルチック艦隊の来攻を前にして日夜猛訓練を督励し，遂によく祖国を護り，また引いて世界歴史をも動かした東郷平八郎の心事を察せられたいものと思います．

これが私のメッセージであります．

A study on a relation between the maximum strength and the power of the muscke with inertia wheel.

by
Michio Ikai and Masahiro Kaneko

パ ワ ー の 測 定

東京大学　猪飼道夫，金子公宥

記録向上とその原動力

陸上にしろ，水泳にしろ，競技の記録は年ごとに改められていく．そこで記録はどこまでも伸びるものだろうか，それともどこかに限界があるのだろうかと，考えざるを得なくなる．人間が生存する限り記録は伸びつづけるものだという人もいる．これに対して，誰も反対することはできないそれは反対する資料がないからである．しかし人間がいくら早く走るようになっても，駿馬のようなスピードは出せないので，この意味では記録に限界があるといえる．ヨクル（Jokl, E）博士は競技記録が年々進歩していく理由として，次の3つを上げている．

第1には，競技に参加する人の数がふえることである．1896年のオリンピックでは，13カ国から285名の選手が参加した．これだけの選手が選抜されるには約5万人の競技者たちがトレーニングされたはずである．それに対し，1964年の東京大会では，100カ国から約10,000名の選手が参加するであろうが，その母体として約1億の競技者たちがトレーニングをうけることであろう．したがって，他の原因をまったくぬきにしても，記録は向上するはずだという．

第2には発育促進現象がその原因の1つになるという．日本人の身長も体重も伸びてきたが，イギリス人，アメリカ人，ドイツ人，すべて伸びつつある．1962年のイギリスの高校生は，ロンドン塔の中にある昔の武士たちのよろいを着ようとしても着ることができない．近ごろの青年たちの方が身体が大きいからである．これと同時に年配になってからでも，活動力が衰えず，活動年令の範囲が広くなった．1952年のオリンピックには，13才から66才までの人が参加したが，これはそのことを示している．

第3の原因は，黒人の参加がふえたことである．ヨクル(Jokl)とカルボーネン（Karvonen, M.J.）（注1）とは1952年のヘルシンキのオリンピックの時の調査をまとめて，黒人が一番競技能力が高く，白人と黄褐色人はこれに劣るといい，その比率は37.3：25：25であるとし，黒人は特にスプリント，中距離走，ハードル，跳躍にすぐれているという．したがって，将来アフリカの独立国がふえて黒人の参加する数がふえれば，ますます記録の向上が期待される．

これに加えて，第4の原因として，トレーニングの進歩があげられなくてはならない．近代トレーニングの特長は，筋力を高めることである．筋力はすべての運動の原動力であるといえる．昔の選手と今の選手の筋力を比較することはできないが，ウエイト・トレーニングが進歩し筋肉が発達したことは確かである．特に「全身的の筋力づくり」や，「種目別の筋力づくり」により，系統的に筋肉トレーニングをすることは，技術の進歩と相まって大きな記録向上への原動力であることに相違ない．

筋力トレーニングの功罪

走にしても，跳躍にしても，投てきにしても，筋力がなくてはよい記録は得られない．スプリンターや，ジャンパーはよく発達した脚の筋肉をもち，投てき選手は太い腕の筋肉をもっている．

近代スポーツ・トレーニングの中核をなすもの

(註1) Jokl, E. and M. J. Karvonen et al: Sports in the Cultural Pattern of the World. A Study of the Olympic Games. 1952 at Helsinki. Institute of Occupational Health. Helsinki, Finland.

はウエイト・トレーニングだといってもよい．ウエイト・トレーニングはそれぞれの種目の練習（practise）だけでは容易にできないような筋力を容易に，しかも望ましい部位に作ってくれるからである．日本でも，いまではウエイト・トレーニングはどの競技種目にも採用されている．しかし初めには，いくらかの「ためらい」と「うたがい」とがあった．いまでもその名残りはある．「ためらい」があればウエイト・トレーニングの利用法を種目ごとに研究すればよい．水泳こそ考えようによっては水中で泳ぐのだから，陸上でのウエイト・トレーニングは不用だともいえる．しかしまた，考え方によっては，水泳の推進力は腕で水をかくことによって生ずるから，陸上で腕の筋力を高めておいた方が賢明だともいえる．事実，腕筋力や脚筋力と水泳スピードとの関係を見ると，相当に高い相関があることがわかる．水泳スピードと総合筋力（背筋力＋握力＋腕筋力＋脚筋力）との間にも密接な関係がある．（注2）

水泳連盟ではこれを参考にして水泳に特有な陸上でのウエイト・トレーニングをあみ出した．その成果は期待された通りに出てきている．

しかし，時にはウエイト・トレーニングが記録の向上に役立たないように見えることがある．跳躍の選手にウエイト・トレーニングを課した時，筋力は著しく増加したが，シーズンに入ってからの跳躍の成績は，予期したようなものでないということもある．そこでコーチも選手もウエイト・トレーニングは跳躍には有害無益だと判断する場合がある．果たして，この判断は正しいものであろうか．

パワー測定のいろいろ

ウエイト・トレーニングの目的は，筋肉をつくり，筋力を高めることである．しかし，記録は筋力そのものではなく，パワーによって決まってくる．したがって，筋力増大が記録の向上に直結するとは限らない．わかりやすい表現を用いれば筋力はこれにスピードの要素が加わって，力×スピード＝パワーという形で，記録を支配するといえる．この式を見れば，スピードが一定ならば力が大きいほどパワーも大きくなるが，スピードが減少すれば，筋力が増してもパワーが大きくなるとは限らない．そして，測定法として力×スピード＝パワーを用いるものが生まれてくる．そのためにはまず，天井から一本の綱を下げ，これにmという質量のおもりをつり下げる．被検者は仰向きに寝て膝を曲げ，このおもりに足の裏をつける．そして力いっぱい膝を伸ばして，このおもりを向こうへつき出す．そして側面からおもりの運動を映画に撮影してスピード（v）を出す．この時，mという重さの物を動かした加速度をαとする．$m\alpha$は加えた力であるから，求める脚筋のパワー（P）は，$P = m\alpha \cdot v$である．

小林氏（注3）は，この方法で脚筋のパワーを測定した．そして次のようにのべている．

「おもりの質量の変化による各種の値の変化を見ると，仕事率（パワー）には極大値があることがわかる．したがって，身体運動にはそれぞれの動作について，仕事率（パワー）が極大値になる負荷があることが考えられるが，力とスピードと同時に要求される運動では，必要とされる負荷での仕事率（パワー）が大きくなるようなトレーニングが有利と思われる」と．

片脚の場合に，膝関節を90度に屈曲したところから伸展した時にはおよそ15kgの負荷（おもり）の時に最大のパワーが出ており，1800ワット（約1.3馬力）である．両脚の場合は約20kgくらいの負荷（おもり）でパワーは最大となり，およそ3500ワット（約2.6馬力）となる．

パワーを表わすにはもう1つの表現がある．それは，一定の時間内にどれだけの大きさの仕事をしたかということである．サージャント・ジャンプをして，床から垂直にとび上がる高さを測定する．その高さは，人体の重心の上がった高さである．この時の体重をwとし，跳躍の高さをhとすればwhは跳躍によってなした仕事である．跳躍台の下にストレインゲージをはりつけておいて，跳躍動作の開始から，足が台を離れるまでに要した時間を測定し，これをtとする．wh/tによりパワーが出る．tという時間にwhという仕事をしたのである．実測するとtはおよそ0.3～0.4

（注2）宮下充正：水泳選手の筋力と技術について，体育の科学，11巻，12号，1961，p.613-618.

（注3）小林一敏：力学的に見た瞬発力，体育の科学，11巻，12号，1961，p.604-607.

秒である．いまかりに70kgの選手が70cmだけとび上がったとすればおよその馬力は次のように計算される．

$70\times0.7\div0.3=16.3\text{kgm/sec}$

$16.3\div75=2.1$馬力

垂直跳（サージャント・ジャンプ）がパワーの測定に用いられるゆえんである．しかし，一般のテストでは跳躍の時間tは測定されないので，個人のパワーは出ない．垂直跳で容易にわかるものは，仕事（体重×高さ）だけである．ただし，跳躍のための時間tは各人で似ているので，仕事はパワーに比例するとみなすことができる．アメリカの体育学専門雑誌“リサーチ・コーターリー”には脚筋のパワーを計るのに，依然として垂直跳を用いている．すなわち，グレイ氏（注4）は，なるべく純粋に脚筋のパワーを見るために，片腕を背に回し，片腕を頭上に伸ばして十分にしゃがんでとび上がり，頭上に伸ばした手の上がった高さで測定するをよしとしている．しかし，自転車エルゴメーターを10秒間踏ませた時の回数をもって，脚筋のスピードを表わすと，スピードと垂直跳との間に＋0.470という低い相関しかないことを見て，その原因がどこにあるかを疑っている．自転車エルゴメーター作業で参加する筋肉と垂直跳に参加する筋肉とは必ずしも一致していないことも，相関の低いことの原因であろう．しかし垂直跳というテストの意義をもう一度考え直してみる必要もあろう．垂直跳の高さは確かに脚筋のパワーを表わすが，体重という固定した負荷に限られているので，筋肉のもつ特性の一部分しか表わしていない．実際のスポーツでは，もっと大きな荷重がかかる場合が多い．これが垂直跳の成績が必ずしも競技の記録に直結しない原因である．しかし，おもしろいことに，垂直跳の仕事量（跳躍高×体重）は，脚筋力（膝伸筋力）と密接な関係があり，陸上選手についてみると，約0.8の相関がある．これは筋力がパワーに非常に関係が深いということを示すものである．

このようにパワーはいろいろの方法で測定することができるが，それぞれ一長一短あり，垂直跳は簡単ではあるが，負荷が一定だという制限がある．おもりを用いる方法は，負荷を種々にかえることができ，脚筋の性質を広汎に調べることができるという利点があるが，映画を用いるという手数がかかる．

そこで，負荷をかえることもできるとともに簡便なものを探してみると，慣性エルゴメーターを使う方法に思い当たる．これはイギリスのA.V. Hill(注5）が1922年に人間の筋肉の最大仕事量及び機械的効率を研究した時に用いたものである．この方法を用いたものには，奥山氏（注6）の研究がある．筆者等は同様の器具を用い，見方を少しかえて筋力とパワーとの関係をみようとした．

その目的は筋力をいかにうまくパワーに変換するかということを知るためである．

慣性エルゴメーターの作成

まず，慣性エルゴメーターを作成することにした．これは鉄製の紡錘型をした動輪が軸を水平にして，その軸が土台に支持されている．動輪は8種の半径の異なる滑車からなり，鋼鉄製の軸の両端はボールベアリングを通して支持され，自由に回転することができる．動輪の体積は6205.8cm³であり，重量は48.6×10^3gである．各滑車には綱（ワイヤー）がかけられるように約5mmの釘が突き出している．引く綱は長さ2m，直径1mmのワイヤーである．大きな力が加わっても，動輪が動かないように，土台にとりつけられた鋼鉄製ピンを動輪の側面の孔に差し込むようになっており，これはまたレバー（梃子）によって容易にはずれるようになっている．計測が終われば回転しつづける動輪を制止するための木製のブロックがとりつけられている．動輪の回転軸の一端に電気接点があり，これをインク書きオッシログラフに接続し，回転速度が記録できる．

動輪に対してなされた仕事（w）は，最大スピード（ω）にいたるまでに力が加わり，仕事がなされたと考えられるので，次の式で表わされる．

（注4）R. K. Gray, K. B. Start, A. Walsh: Relationship between Leg Speed and Leg Power. Research Quarterly, 33巻, 1962年10月, p. 395–399.〔Olympia, No. 16. 1963, 2月. p. 38参照〕

（注5）A. V. Hill: The maxinwm work of human muscles and their mosr economical speed. J. Physiol. Vol. 56. 1922. p. 19.

（注6）奥山美佐雄：生体筋肉の最大仕事について，労働科学，9巻，5号，1932. p. 501–524.

$$W=\frac{1}{2}I\omega^2$$

ここでIは動輪の慣性モーメント（注7）であり，計算の結果，次のようになった．（注）

$$I=27.4\times10^5 gcm^2$$

したがって，仕事は次のように，動輪の回転の角速度（ω）によって測定できる．

$$W=\tfrac{1}{2}27.4\times10^5\times\omega^2 \text{ Joule}$$

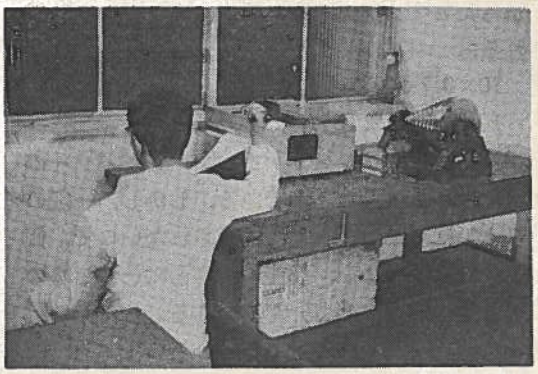
半径の異なる滑車上で動輪を引く時，負荷はそれぞれの場合で異なってくる．すなわち，大きい半径では負荷は小さくなり，小さい半径では負荷が大きくなる．この半径による負荷の大きさが等価質量（Equivalent mass）である．半径をγとする時，その等価質量はI/γ^2で表わされる．この時はIは動輪の慣性モーメントである．本実験に使用した慣性エルゴメーターの滑車の半径とそれに相当する等価質量は次のようである．

滑車No.	1	2	3	4	5	6	7	8
半径（cm）	2.0	3.5	5.0	6.5	8.0	9.5	11.0	12.5
等価質量(kg)	685.0	223.0	109.6	64.8	42.8	30.3	22.6	17.5

測　定　方　法

まず，ワイヤーを滑車にまき，動輪をピンでとめる．この時，滑車に巻く部分のワイヤーの長さを一定になるようにする．被検者（選手）は，椅子にかけ，腕を直角に曲げ，手にワイヤーの一端についたハンドルをもち，最大の力を発揮してワイヤーを引く．この時滑車はピンでとめてあるので動かない．そこで，最大筋力を測定する．最大筋力が十分に発揮されたところを見計らって，レバーを押してピンをはずすと，被検者の筋が収縮するので動輪は回転する．そこで，動輪の回転速度がインク書きオッシログラフに½回転ごとのマークを記録する．

腕屈曲の場合は，綱を引く方向と垂直方向に向かって接座し，側方に腕を上げ，上腕は支持台に密着させ，肘関節角を90度とし，綱についたハンドルを握る．また電接装置により，滑車に対して筋力が作用した時間を記録できるようにした．腕の屈曲は，滑車のピンが抜けると同時に起きるようにしてある．しかし比較のために，滑車のピンを抜いておいて腕を随意的に屈曲させる方法も用いた．結果には多少の違いが見られたが，本質的には違いはない．脚伸展の場合は，被検者（選手）が，脚筋力測定用の高い椅子にすわり，下腿を垂直にさげ足首にワイヤーの端につけたベルトを巻き，手は肘掛におく．膝伸展筋にいっぱいの力を入れて，膝を伸ばすように努力する．この時の，最大筋力はストレインゲージで電気的に記録され



第1図　慣性エルゴメーターで腕のパワーを測定する装置（東京大学体育研究室1962）

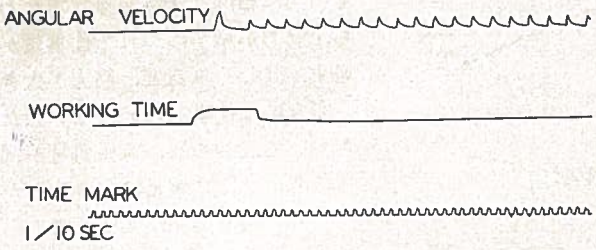
第2図　慣性エルゴメーターで脚のパワーを測定する装置（東京大学体育研究室1962）

（注7）慣性モーメント（I）は各滑車の慣性モーメント（I′）の和である．すなわち$I=I'_1+I'_2+\cdots\cdots+I'_8$，ただし，$I'=\int_0^{2\pi}\int_0^{R}(\rho\gamma'.d\theta.d\gamma)\gamma^2$ である．さらに，動輪に綱をまき他端に一定の質量mなる物体をつるし一定の高さhから落下させるとこのときのエネルギーは次の関係式であらわされる．

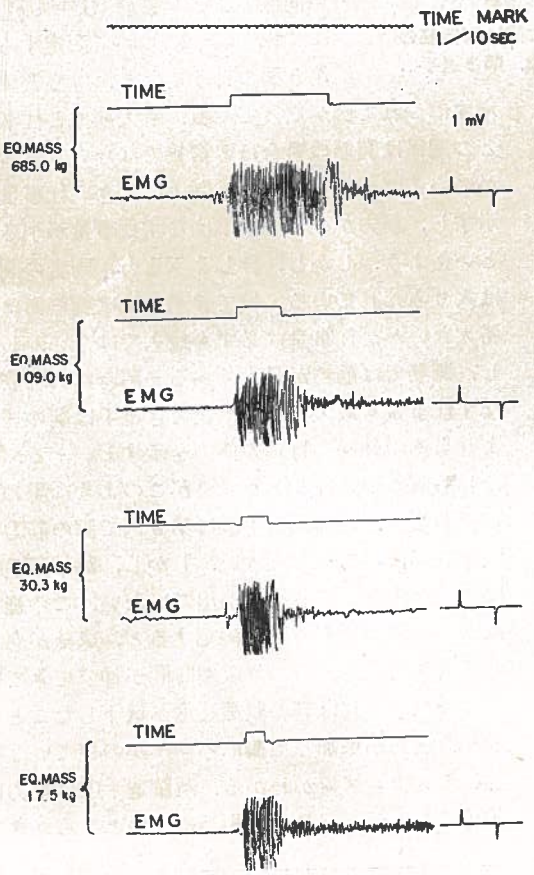
$$mgh=\frac{1}{2}mv^2+\frac{1}{2}I\omega^2$$

この実験により動輪の慣性モーメント（定数）はさらに確かめられた．

る．最大筋力が発揮されたところで，滑車のピンをはずすと膝は伸びるとともに，動輪を回転させるようになる．滑車の釘にかけてあるワイヤーの端は輪になっており，力がぬけた直後に，動輪の回転を妨げることなく，はずれるようになっている．



第3図　慣性エルゴメーターの回転速度(上)，力の作用時間(中)，及び時間記録（下）である



第4図　慣性エルゴメーターの等価質量（kg）の変化とともにカの作用時間（Time），及び筋電図（EMG）の変化する様子を示す

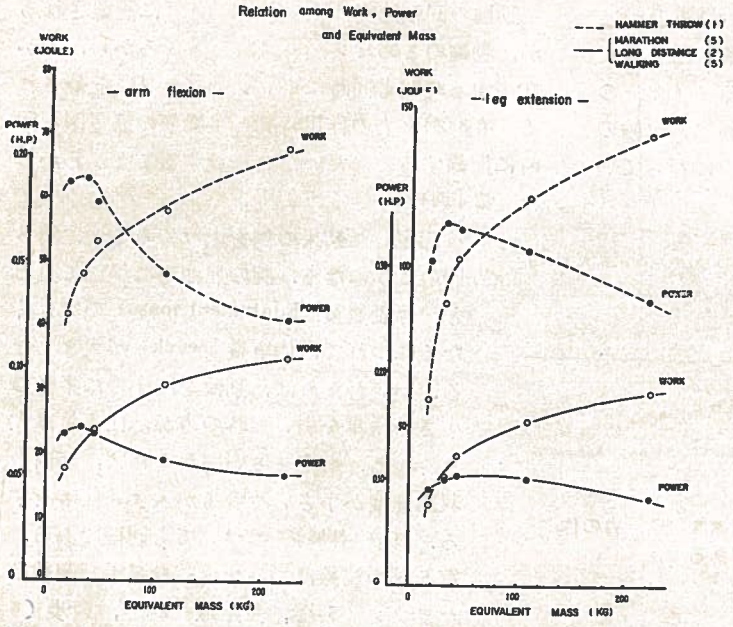
動輪の回転速度はオッシログラフに記録されるが，動輪のとめピンが外されたところから，力が作用する時間も同時にオッシログラフに記録される（第3図）．力の作用時間と主働筋の筋電図を同時に記録すると，だいたい一致することがわかった（第4図）．

測定した結果の例を上げてみると，第5図のようになる．腕の屈曲力について見ると，等価質量（Equivalent mass）の大きくなるにつれて，仕事量（work）が大きくなる．いいかえれば，動輪を回すのに半径の小さい滑車を引いた時の方が，仕事量は大きくなる．もう一度いいかえれば，筋肉の収縮速度が小さい時の方が大きい仕事をする．脚筋（伸展筋）についても同様である．第5図の波線は，ハンマー投選手，実線はマラソン（5名），長距離（2名），競歩（5名）の選手の平均である．傾向は両者とも似ているが，仕事量に大きな開きがある．ハンマー投選手の最大の仕事量は約68ジュール，持久競技では35ジュールであり，後者は前者の約½である．脚筋について見ると，ハンマー投選手では最大値が約140ジュール，持久競技では60ジュールであり，やはり後者は前者の½である．次に，力を作用させた時間で，仕事量を割ると，パワーが出てくるが，ハンマー投選手の腕屈曲のパワーは0.18馬力，持久競技では0.07馬力である．脚伸筋ではハンマー投選手で0.32馬力，持久競技で0.10馬力である．このように馬力で比較すると，腕で2.6：1，脚で3：1である．また仕事量とパワーとは第6図に見る程度にかなり高い相関がある．この関係は等価質量が異なるにつれてかわってくるので，等価質量が同一の場合にはこの程度に仕事量をパワーとよみかえることができる．

こういう意味で仕事量を，パワーということばにおきかえてみることができる．

陸上競技選手の筋力とパワーとの関係

（1）腕筋力とパワーとの関係

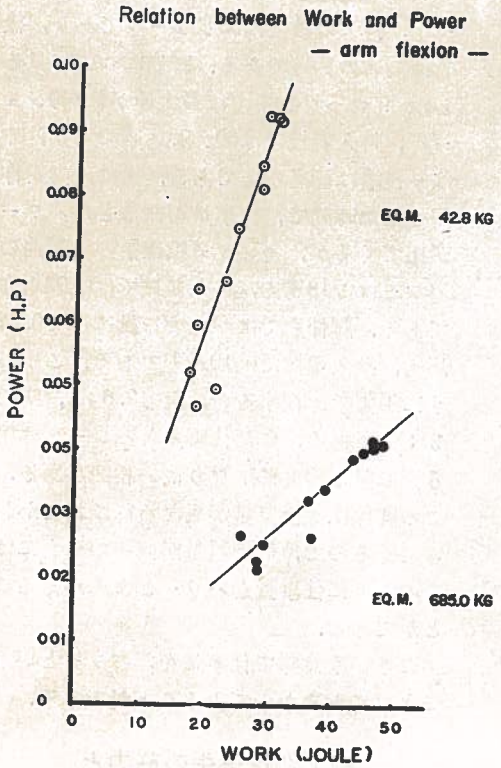


第5図 慣性エルゴメーターによる等価質量（横軸）と仕事量（Work），及びパワー（Power）との関係を示す．左図は腕屈筋，右図は脚伸筋のものである．波線はハンマー投，実線はマラソン，長距離，競歩選手

腕の屈筋（主として上腕二頭筋）について測定した数字から，最大筋力と仕事量との関係を等価質量ごとに図にすると第7図のようになる．等価質量が増加するにつれて関係図が立ってくるが，いずれも相当に相関々係がある．すなわち，筋力が増すにつれて仕事量が増す．詳しくみると，筋力が大きい割合には仕事量の高くない人たちもいる．この時，等価質量が同一の時には，仕事量はパワーとかなり高い相関関係があると考えられるので，筋力が大きいほどパワーが大きいという傾向があるということができる．

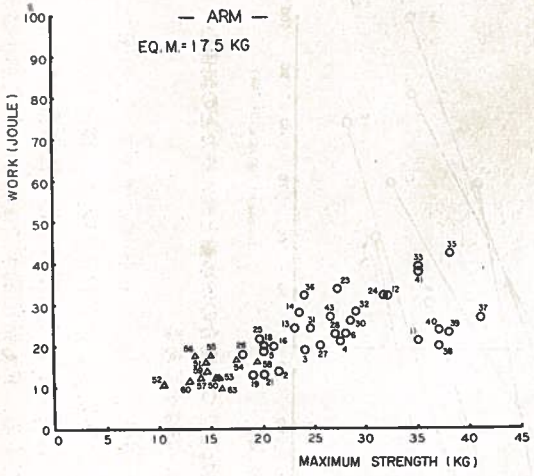
（2） 脚筋力とパワーとの関係

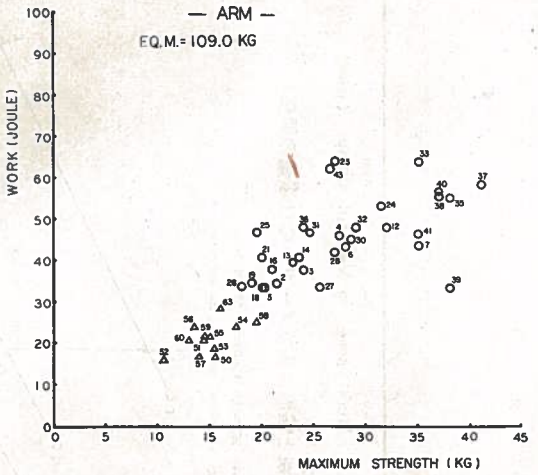
同様のことを脚筋（膝伸展筋，特に大腿四頭筋）について測定すると第8図のようになる．等価質量が増すにつれて図が立ってくる．最大筋力と仕事量との関係は腕筋の場合ほど密接ではない．おおまかにいえば，筋力の大きい選手は大きい仕事量を示すし，筋力が小さい選手はなす仕事量が小さいといえよう．しかし，詳しくみると，両者の関係は入りみだれている．投てき選手㊲は腕筋力は一番大きいが，仕事量は必ずも最大ではない．しかし，脚筋では筋力が最大であると同時に脚伸筋のなす仕事量も最大である．投てき選手は腕の屈曲よりも膝の伸展に特別の能力を示すといえる．すなわち脚のつっぱりとキックがこのように現われるであろう．走高跳選手③は第8図で脚の筋力も大きいが，パワーも大きい．しかし，跳躍選手⑥は筋力は大きいがパワーが出ていない．この選手について全身反応時間を測定すると，成績が悪くなってきている．特に筋収縮時間が伸びてきている（注8）．これは筋の収縮速度が低下したことであり，筋力が増加した割にパワーがのびていないというメカニズムがわかる．跳躍選手⑤は筋力は70kgであるが，パワーも相当によいところへきて

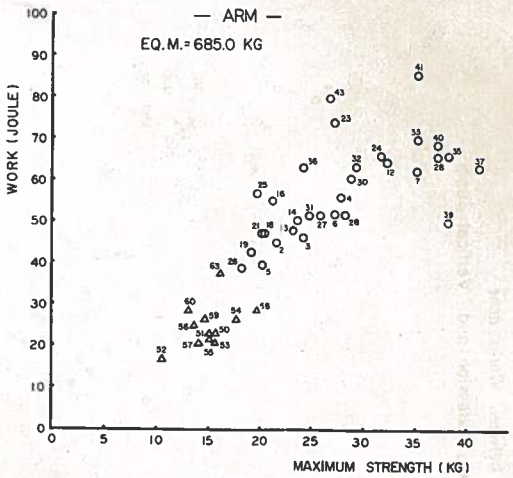


第6図 慣性エルゴメーターの仕事量（ジュール）とパワー（馬力）との関係．白丸は等価質量の小さい場合，黒丸は大きい場合である

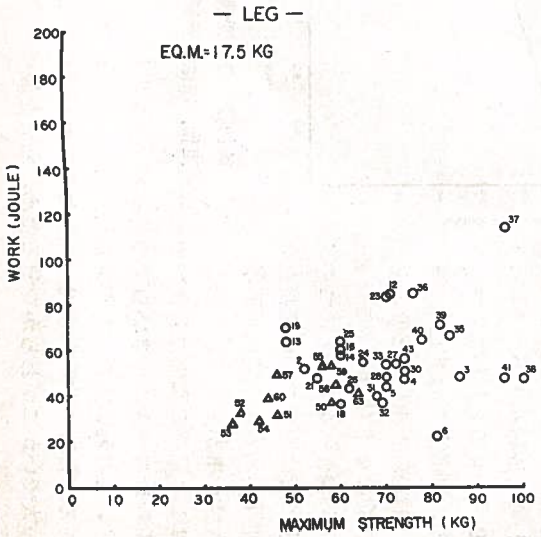
（注8） 猪飼道夫・浅見高明・芝山秀太郎：全身反応時間の研究とその応用 OLYMPIA. No. 7, 1961, p. 210–219.

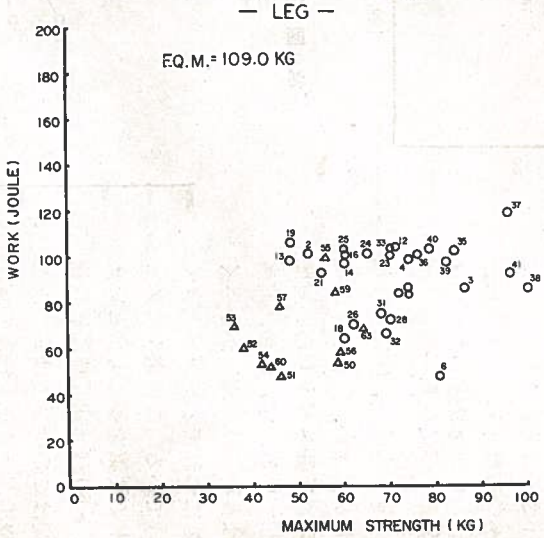


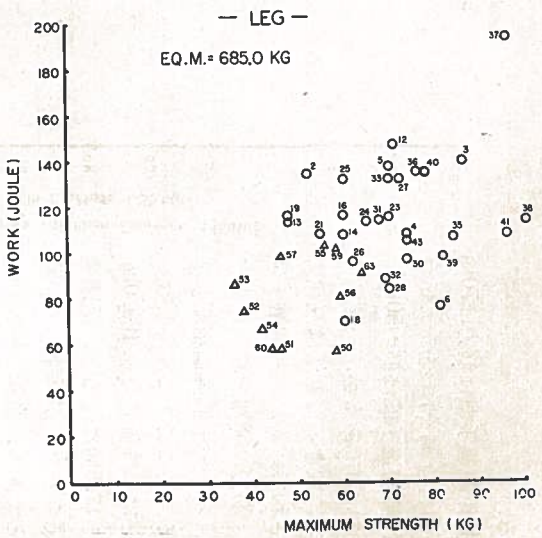




第 7 図　腕屈筋の最大筋力と仕事量との関係



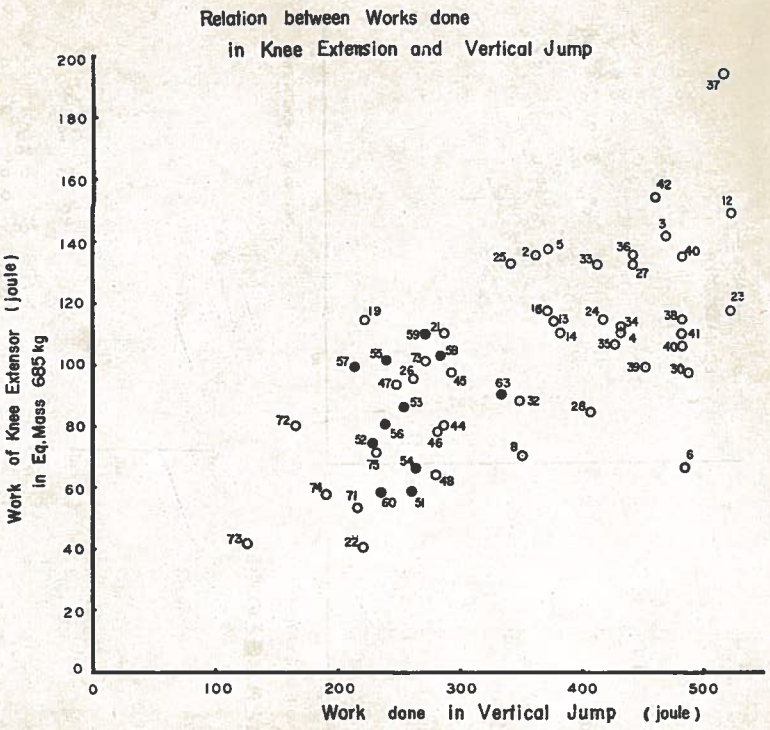




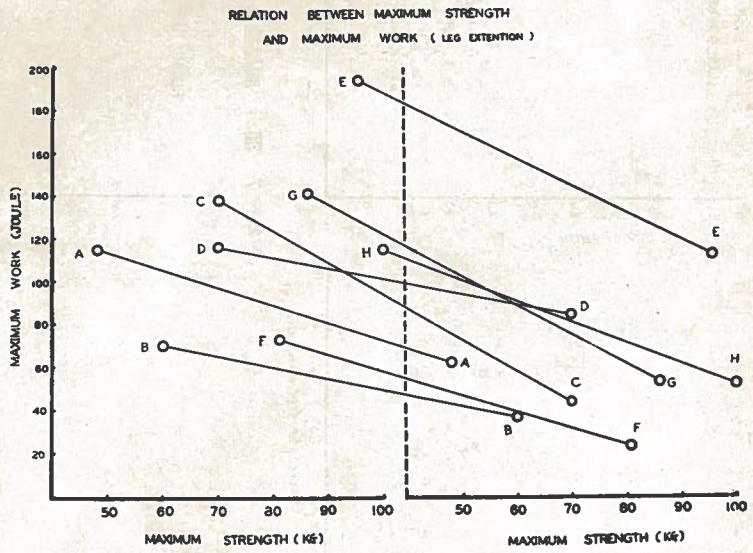
第 8 図　脚伸筋の最大筋力と仕事量との関係

いる．

短距離選手⑫は筋力は70kgで相当に高く，パワーも高い．障害選手②は筋力50kgで小さい方であるが，パワーは相当に大きい．女子は三角で示されているが，跳躍選手㊾は，筋力は58kgで相当に大きく，パワーも筋力に相応している．ここで1つ注目したいことは，等価質量が109.0kgから17.5kgになると，跳躍選手③のパワーが低下していることである．負荷（等価質量）が小さくなるにつれて，パワーが急に低下しているのは，スピードの要素が足りないことを示している．この選手③の全身反応時間，特に筋収縮時間が大きい．障害選手㉓は跳躍選手③とおもしろい対照をしている．すなわち，前者では負荷（等価質量）が小さくなるにつれてパワーが大きくなっている．この選手はスピードの要素を多くもつといえる．全身反応時間，特に筋収縮時間はこの選手では短い．この選手が垂直跳を行なう時はきわめて成績がよい．それは第9図を見るとわかる．すなわち，垂直跳でなす仕事（体重×跳躍高）を横軸にとり，膝伸展筋のなす仕事（等価質量685kgの場合）をとると，この選手㉓では両者の間に密接な関連性があるが，特に垂直跳でなす仕事が大きい．このことはこの選手の脚筋は自分の体重程度の割合に小さい負荷の時にパワーを出しやすい人だといえる．もう少し筋力を高めるべきである．負荷（等価質量）をかえた時の仕事量が同一人でいかにかわるかを見るため，両者を並べこれを直線で結ぶと第10図ができる．この図で，左側は負荷大，右側は小である．Gは走高跳選手で，負荷が小さくなるにつれて仕事量の序列は落ちてくる．Fも跳躍選手であるが，負荷が小さく



第9図　垂直跳と慣性エルゴメーターの仕事量の関係



第10図　等価質量の異なる2つの場合の仕事量と最大筋力との関係の変化，左は等価質量大，右は小である

なってさらに落ちてくる．同じく跳躍選手でも，Dは筋力は弱いが仕事量は割合に大きく，負荷が小さくなると序列が上になってくる．一番上のEは投てき選手であり，負荷の大小にかかわらず仕事量は大きく序列は高い．しかしやはり負荷が小さくなるにつれて他のものに近づいてくる．一番下にあるBは中距離選手であり，負荷が小さくなると仕事量の序列は少し上がる．一般に負荷（等価質量）が小さくなるにつれて，仕事量がさらに低下するのはスピードの要素が弱いのであり，全身反応時間の筋収縮時間が長いことが多い．

（第7，8図中の番号は，短距離12～16，中距離17～19，障害2, 23～26，跳躍3～6，27～36，投てき7，37～42，十種43，女子11，50～63，である．）

筋力からパワーへの発展

筋肉は収縮するということが最も大きな機能である．そして筋肉が収縮しようとする時，長さをかえないように，ひっぱっておろうとすれば力がいる．この力を秤ではかればそれが筋力となる．このような収縮がいわゆる等尺性収縮であり，いわゆる筋力というものは等尺性収縮で測定されたものである．これに対して，スポーツでは多くの場合は筋肉は力を発生しながらその長さをかえる．相撲のつっぱりでは筋は長さをかえない．これは等尺性収縮である．走・跳・投・泳などはすべて筋肉は力を出しながらちぢむ，いわゆる等張力性収縮である．パワーは後者，すなわち筋肉が力を出しながらちぢむ場合に問題になる．いいかえれば，動的筋力とか，瞬発筋力とかいうものに相当する．体力測定で普通握力，背筋力，脚力，腕力などというふうに筋力をはかっているのは，等尺性収縮であるので，パワー＝力×スピードの中の力の部分を知るにすぎない．したがって，筋力がわかっただけで，パワーがわかるとは限らない．筋力が増してもスピードがへればパワーは増加しない．このスピードは全身反応時間の筋収縮時間として測定できる．筋力があり，筋収縮時間が短かければ，パワーがあるといえる．これだけでも，ある程度は見当がつくが，もう少し直接的にパワーそのものを測ろうというのが，ここにあげた試みである．測ってみると，筋力とパワーはおおまかにいえば平行するが，個人により相当のばらつきがある．これはスピードに差異があるためである．筋力はふえたが，記録が上がらない人を調べてみるとパワーが出ていない．この人の筋収縮時間を調べてみると他に劣っている．したがって，この人は筋収縮を敏捷に行なうトレーニングを加味すればよい．きめられた合図に対して敏捷に行動するというトレーニングを入れるのも一策であろう．

また，一方において筋肉を十分に解緊する能力を養うことも必要である．敏捷な行動の前には必要な解緊の一瞬があるはずだからである．筋力トレーニングとうらはらに，リラクセーションのトレーニングもいる．筋力にしても，筋のスピードにしても，その背景には神経の支配が存在している．したがって，筋肉をつくっただけではその半ばをつくったにすぎない．筋肉の全機能を発揮するには神経が全機能を発揮しなくてはならない．それをいいかえれば，神経衝撃（インパルス）の集中がよく，それが長く維持されることである．これによって筋肉は大きい力を出すことができると同時に速く収縮することができる．こうなってはじめて，筋力はパワーとして働くのである．ペルギーのパワー・トレーニングと称するものも，これをねらってはじめて効果がある．

しかし，筋力をいかに巧みにパワーに発展させるかについては，猫や犬など動物の行動に多くを学ぶべきではなかろうか．そこにパワー・トレーニングの真髄があるようだ．

〔座　談　会〕

戦いの場における“地の利”

―― 出　席　者 ――

大島　鎌吉：選手強化対策本部副本部長
東　俊郎：スポーツ科学研究委員会委員長
加藤　橘夫：選手強化対策本部常任委員
猪飼　道夫：スポーツ科学研究委員
石河　利寛：スポーツ科学研究委員
太田　哲男：スポーツ科学研究委員
瀬谷　正敏：青山学院大学心理学教授
中原　乾二：選手強化対策本部常任委員
村田恒太郎：レスリング協会強化コーチ
前田　豊：バレーボール協会理事長
小林　定義：ホッケー協会強化コーチ
小野　喬：体操競技選手

×　　×　　×

東京オリンピック選手強化対策本部では，このたびかねて関心を寄せられていた未知の問題“地の利”についてその本質を究明する試みがなされた．“地の利”は“人の和”と共に戦いの場の鉄則であるといわれるが，それは経験的に肯定されていながら，では果たして何であるかについて検討が加えられることがなかった．この座談会は学者研究者に現場のコーチを混えて未知の，しかし実在する問題にとり組まれたものであるが，これはわが国ではもちろん，諸外国でもかつて行なわれなかった初の試みであろう．

×　　×　　×

大島　過去のオリンピックの実例から見ても，一般的な常識から考えても，オリンピックを開催する国には“地の利”というものがあるようである．それが事実であるとすればメダルの数にも関係してくるので，この際，①“地の利”というものがあるのかどうか，②あるとすればそれはいったいどういうもので，③どういう影響をもたらすのか，④さらに検討を要する問題は何か，ということについてみなさんで検討願いたい．司会は加藤さんにお願いしたい．

加藤　過去のオリンピック例を見ると第１表のように開催国はどうも有利だ．つまり“地の利”があることを歴然と示している．ではいったいその“地の利”とは何か，これを各競技団体の方々の経験に心理学，生理学の立場の解しゃくを加えてディスカッションの形で導き出していく必要がある．話を進めるため一応問題点として次の項目をあげてみたい．

1. 開催国としての特徴点
   ①国民のオリンピックに対する意識と選手に対する無言の応援
   ②スポーツ団体及びコーチ，選手たちの意気込みや責任感
   ③国家および国民の援助
   ④その他コンディションづくりの利点（高地でトレーニングし直ちに競技場にもちこむ等）
2. 海外遠征の場合の問題点
   ①旅行の疲労（乗物，宿泊，食事，睡眠，練習，言葉の問題，生活のリズムの変化など）

第１表　各回の地元の金メダル獲得数
（　）内は前回の獲得数を示す．

第２回大会（フランス）	19	（５）
第３回大会（アメリカ）	68	(18)
第４回大会（イギリス）	57	（１）
第５回大会（スウェーデン）	24	（８）
第７回大会（ベルギー）	17	（２）
第８回大会（フランス）	15	（９）
第９回大会（オランダ）	8	（４）
第10回大会（アメリカ）	44	(22)
第11回大会（ドイツ）	38	（５）
第14回大会（イギリス）	4	（４）
第15回大会（フィンランド）	6	(10)
第16回大会（オーストラリア）	13	（６）
第17回大会（イタリア）	13	（８）
第18回大会（日本）	?	（４）

M. IKAI & K. ISHII: An Electromyographic Study on Physiological and Psychological Limits of Human Strength.

筋力の生理的限界と心理的限界の筋電図学的研究

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I 緒　言

体力のうちで，筋力について考えてみると，人の最大筋力を決定するものは，筋の断面積という構造的要素と，筋を支配する運動単位の興奮状態という機能的要素とである．そして，構造的の要素は個人に特有のものであるとともに，個人の発育段階に応じて一定の値を示すものである．これにたいして，機能的要素は，個人に特有ではあるが，一定の発育段階においても必ずしも一定したものではなく，一日の中でも，また継時的な測定の場合においても，つねに変動するものである．さきに，猪飼は A. H Steinhaus[3)4)] とともに，この二つの要素を考察し，ここにいう，構造的要素によつてきまる筋力の上限を筋力の生理的限界（physiological limit）と名づけ，ここにいう機能的要素によつてきまる筋力の上限を心理的限界（psychological limit）と名づけた．生理的といい，心理的といつても，あくまで便宜的の名称であり，前者が，より身体構造に支配されるものであり，後者がより神経活動に支配されるものであり，したがつて，いわゆる心理的条件をふくむという意味である．この点の細部の論議については別紙に述べた[7)]．

体力測定の意味で筋力を測定するとき，同一人でも，日により，時によりその最大筋力は多少の変動を示すものであり，その変動の原因の一部を占めるものは，上述の心理的限界の変動によると解することができる．いいかえれば，心理的限界が低下した状態では，たとえ同じ断面積をもつ筋であつても低い筋力しか示すことはできない．

猪飼と A. H Steinhaus[4)] は，ケーブル・テンシオメーターを用い，上腕屈筋の最大筋力を1分間に1回の割で測定し，30分に及んだが，一般的には次第に低下し，30分後には最初の値の約10%の低下を示した．この経過において，最大筋力発揮の時点よりも2〜10秒先行してピストル音を与えるとき，最大筋力が増大することを認めた．また，同様にこの経過のうちに，自然な「かけ声」をかけさせるときも最大筋力が増大することを認めた．著者らは，このような最大筋力の増大の機構として心理的限界が上昇すると想定したわけである．それまで大脳に存在していた抑制が，音によつて抑制されたものであると考え，いわゆる条件反射における脱制止(disinhibition)と解釈した．

さらに，Amphetamine sulphate を服用させたときの最大筋力をしらべたが，服用後30〜40分で筋力の増大を認めた．この機構についても，同様にこの薬物による大脳の抑制の減退を考えた．

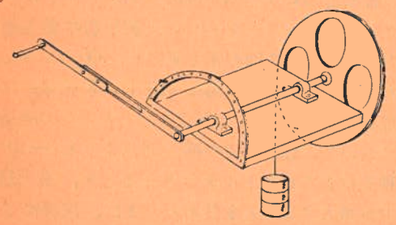
本実験においては，上述の想定された機構をたしかめるために，筋力を発揮する主働筋への運動単位の神経衝撃を記録し，それと諸種の実験条件による最大筋力の増減との関係を明らかにしようとした．

II 実験方法

実験を大きく二つに分けることができる．

その一つは，腕エルゴメーターを用いるものであり，これでは最大筋力以下の筋力を出しつづける場合の運動単位の神経衝撃を筋電図によつて見るものである．他の一つは，ストレインゲージ筋力計を用いるものであり，これでは最大筋力を出しつづける場合の運動単位の神経衝撃を筋電図により見るものである．両者において，運動単位の神経衝撃を見るため，筋の上にはりつけた表面電極を介して，筋電図を記録した．

第1図　腕エルゴメーターの構造



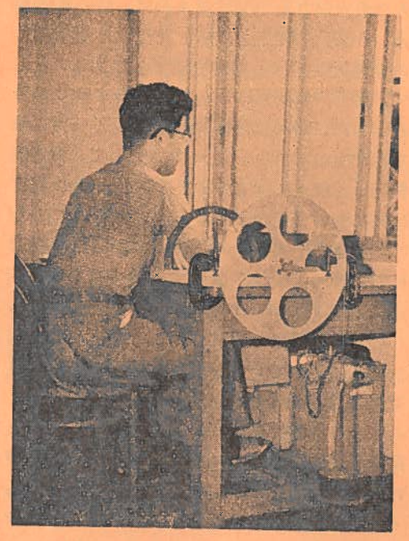
(1)　腕エルゴメーターを用いる方法

腕エルゴメーターは，第1図に示すように，東大体育学研究室[5]において設計作成されたものであり，肘関節がいかなる角度にあつても，常に荷重が前腕の長軸に直角に作用するようになつている．すなわち，筋にかかる力の能率が常に一定であるという長所をもつている．図において明らかな如く，被検者はエルゴメーターのアームのハンドルを握るのであるが，アームの長さは，被検者の前腕の長さにあわせるようになつている．滑車には鋼鉄線にさげた錘により荷重をかけることができる．円弧の上には10度毎にきざんだ小孔があけてあり，この小孔にさしこむ「とめ金」の位置により，前腕を何度まで屈曲させるかということが規定される．この実験では，肘関節が120度から90度にまで屈曲するようにしたので，「とめ金」の位置は，図のようになる．また測定にさいしは肘や上腕や肩の動くのを止める必要がある．このために，第2図に見られるように，120度の開きをもつた「腕当て」を作成した．

これを用いることにより，作業中の姿勢を一定に保つことができるばかりでなく，肘関節の回転軸をエルゴメーターの滑車の回転軸とつねに一致させることができる．

以上のような構造の腕エルゴメーターを用い，上腕屈曲筋の筋作業を行うにあたつては次のような手順をとつた．

第2図　腕エルゴメーターによる筋作業．この写真で肘当てを見ることができる．



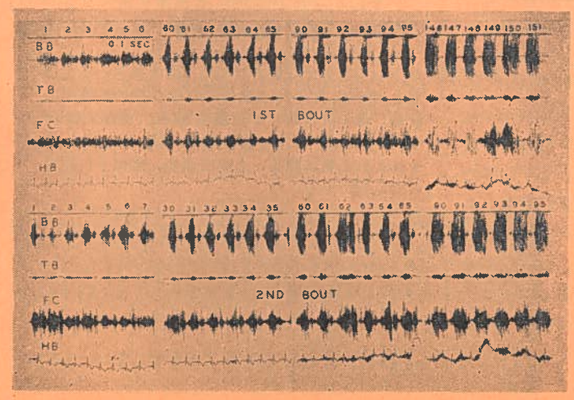
1) 第2図に示すような姿勢で，エルゴメーターに位置し，滑車にかけた鋼鉄線の下端の錘りを外して，床に固定したかぎに掛け，この鋼鉄線にケーブルテンシオメーター (Cable-tensiometer, California) を装着し，エルゴメーターのハンドルをもちあげるように努力して，上腕屈曲線の最大筋力を等尺性に測定した．

2) 最大筋力の1/3の重さの錘りをエルゴメーターにかける．最大筋力が30kgであるならば，10kgの錘りを用いる．

3) メトロノームにあわせて，1秒に1回のテンポで肘関節を屈曲し，エルゴメーターのアームが「とめ金」で停止するまで錘りをもちあげ，これをできるだけ多く反復し，その反復回数をかぞえ，それをもつて筋持久力とする．リズムにあわなくなつたとき，または「とめ金」にふれなくなつたときに，ただちに作業を停止させ，それまでの作業回数を数える．このようにして筋持久力をあらわすことができるが，さらにその後5分の休息を挿入したのち，再び同様の作業を行い，反復回数を測定することにより，筋の疲労からの回復能力をしらべることができる．すなわち，第1回試行のときの回数を N_1 とし，第2回目の試行のときの回数を N_2 とするとき，N_2/N_1 という比率は，回復率を示すといえる．また，N_1+N_2 は綜合した持久力を示すことになる．第1回試行だけで持久力を見る方法をここでは単純法 (one bout method) とよび，休息をはさむ2回を試行による方法を重復法 (two bouts method) とよぶ．

以上のエルゴメーター作業において，上腕二頭筋，上腕三頭筋，撓側手根屈筋の皮膚の上に直径約5mmの銀板電極を2個電気糊ではりつけ，これを介して筋にあらわれる活動電位を導出し，三栄ペン書き多元電気記録装置によつて記録した．電極は筋の中央部で筋線維の走行方向に沿い，約2cmの間隔をおいてはりつけた．またその二つの電極の中間にさらに一つの電極をはりつけ，これを接地した．この結果，記録はすべて普通の実験室で行うことができ，遮蔽室を使う必要がなかつた．第3図はその記録の1例である．

第3図　腕エルゴメーターによる筋作業の経過における主働筋その他の筋の筋電図．筋の収縮は1秒に1回．最上段の数字は反復回数，時間記録は0.1秒，BB, TB, FCはそれぞれ上腕二頭筋，上腕三頭筋，橈側手根屈筋の筋電図を示す．またHBは心電図による心搏の記録である．IST BOUT, 2ND BOUTはそれぞれ第1回および第2回試行を意味し，この間に5分間の休息をはさんでいる．

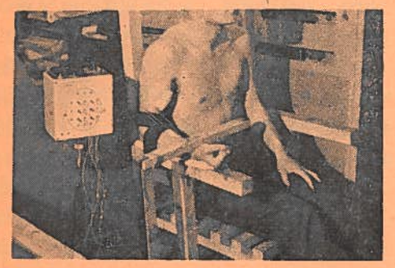


(2)　ストレインゲージ筋力計を用いる方法

上述の筋エルゴメーターでは，荷重は最大筋力以下の一定の値 (1/3) に固定されているが，これとは別に最大筋力をいかに出しつづけることができるかということを見る方法がある．この目的のためストレインゲージ筋力計を設計作成した．これは抵抗線の伸縮が抵抗値を変化させることを利用するものであり，ストレインゲージは新興通信工業製の S_{21} 型を用いた．

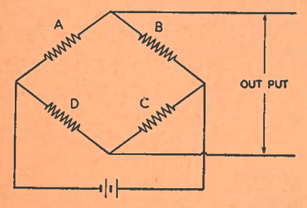
筋力計は第4図に見られるように，4×2×50cmの木製の棒の両端を鉄製の枠で固定し，ストレインゲージを木製の棒の端から長さの1/4の位置に貼布した．また，貼布方向は棒の長軸の方向に平行にした．これがアクテイブゲージとなる．棒の連続的な歪から生ずるゲージの熱変化による抵抗値の変化を補償するためアクテイブゲージと直角に他のゲージを貼布した．こ

第4図 ストレインゲージ筋力計による最大筋力の反復測定．前腕と直角にある水平の木の棒にはストレインゲージが貼布されている．



れが補償ゲージとなる．ストレインゲージ4枚を第5図のようにホイストンブリッジ回路に接続し，A とC とをアクテイブゲージ，B, D を補償ゲージとしたのは，2倍の感度を得るためである．電源には 4V の電池を用い，out put を三栄多元電気記録装置に導き，インク書きオツシログラフで記録した．

第5図 ストレインゲージ A, B, C, D, の貼布の様式



肘をベルトで固定し，上腕屈曲筋を一気に収縮させ，木製の棒の中央を前腕の手関節に近い部分で上方に押しあげ，最大筋力を記録する．被検者は第4図のように位置し，両脚をのばして台の上にのせ，左手は楽にのばして，膝の上にのせ，右腕の最大筋力をはかるときに，左手や両脚で台面その他の部分を支持しないようにする．被検者は，始めの合図とともに，2秒に1回のテンポで最大筋力を発揮するようにし，300回～600回に及ぶ．テンポを保つには前と同様に，メトロノームを用いた．

最大筋力の消長と運動単位の神経衝撃との関係をみるためには，次の3種の方法を用いた．

(a) 持久作業の場合

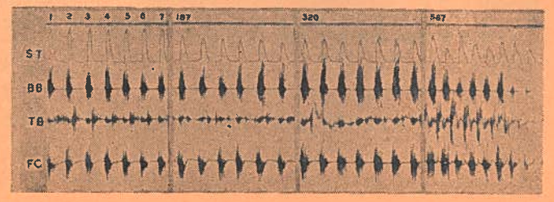
2秒に1回のテンポで最大筋力を出していくとき，毎回最大努力が行われるわけであるにも拘らず，最大筋力は変動を示しながら，回数を重ねるにつれて減少してくる．しかし，このとき，上腕二頭筋，上腕三頭筋，撓側手根屈筋への神経衝撃は必ずしも筋力と平行せず，独自の消長を示す．その1例は第6図である．そして，ついに作業を連続することができなくなるまで努力をつづける．

(b) shot および shout の場合

2秒に1回のテンポで最大筋力を出していくとき，毎回が最大努力で行われるにも拘らず，最大筋力は減少を示している．このとき，前述のようにピストル音（shot）を最大筋力発揮の直前（約1秒前）に与えるとき，これにつづく最大筋力の増大がある場合に，主働筋の運動単位の神経衝撃が増加するかどうかをしらべた．

また，これとは別に被検者自身に「かけ声」(shout) をかけさせたとき，筋力の増大がある場合に，主働筋の運動単位の神経衝撃は増加するかどうかをしらべた．

第6図 ストレインゲージ筋力計による最大筋力の反復測定と同時に行った主働筋その他の筋の筋電図の記録．最上段の数字は反復の回数，時間記録は0.1秒である．ST は最大筋力，BB, TB, FC はそれぞれ上腕二頭筋，上腕三頭筋，撓側手根屈筋の筋電図である．



(c) Amphetamine sulphate を投与した場合

健康な被検者に 10～16mg の Amphetamine sulphate の錠剤を服用させ，その後の最大筋力を逐次的に測定し，薬剤の効果を見た．また，その経過において最大筋力の消長と筋力への運動単位の神経衝撃の消長との関係をしらべた，さらに，筋力の減退のある時期に Shot, あるいは Shout を与え，そのときの最大筋力の変化と，主働筋の運動単位の神経衝撃の変化とをしらべた．

III 実験成績

以上の方法により得られた成績は次の通りである．これを腕エルゴメーターを用いた実験と，ストレインゲージ筋力計を用いた実験とにわけて記述する．

1. 腕エルゴメーターを用いた実験

腕エルゴメーターを用い，最大筋力の 1/3 の荷重のをかけて，1秒1回のテンポで肘関節を 120 度から 90 度まで，30 度だけ屈曲して錘りをもちあげる作業を，できるだけ長時間くりかえす作業中の上腕二頭筋（BB），上腕三頭筋（TB），撓側手根屈筋（FC）の筋電図は第3図に示したようなものである．この被検者は持久力が相当に高い方であり，第1回試行では 151 回行つている．記録は便宜上初期，中期の2期，終期のそれぞれ4回ずつのほかは割愛したものである．図の最上段は肘の反復回数を示したものである．図の最下段は心搏を示す心電図（HB）である．本測定はエルゴメーターを用い重複法によつたものであり，151 回の屈曲を終了したあと，5分間の休息をおき，再び第1回試行と同様に第二回試行を行い，95 回の屈曲を以て作業は不可能となつた．

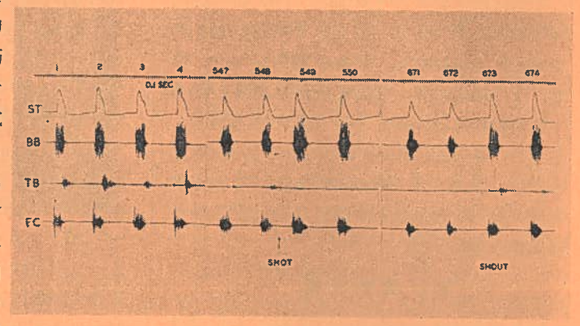
図において明らかなように，主働筋である上腕二頭筋の筋電図は，初期には小さいが，中期，終期と進行するにつれて増大してくる．このような筋電図の振幅の増大は運動単位の神経衝撃の増大を示すものである．さらにくわしく見ると，1～6回目の筋電図は振幅の小さい割合に，持続時間が長く，ほとんど，屈曲と屈曲との間において放電が断絶することがないほどである．これは，肘が屈曲して錘りをもちあげる時期のみならず，錘をおろして肘を伸展するときも，上腕二頭筋が活動していることであり，動作の上からは，肘の伸展の場合に錘を放り出していないことであり，動作がなめらかである．これにたいして，60～65 回という中期になると，錘を持ちあげるという作業に努力が集中してくるとともに，その中間期に放電の減少が見られる．これは肘をのばすときに，錘を放り出す傾向が出ていることになる．しかし，小さい放電が見られることは，錘を放り出すことを阻止しようとする努力が残つていることを示す．90～95 回においても同様であるが，この傾向が強くなつている．さらに，終期の 146～151 回にいたると，錘を持ちあげるための努力の集中が極度となり，しかもその中間の放電が全くなくなる．これは完全な錘の放り出しを示す．しかも，錘をもちあげるときの放電は振幅においても，その持続においても増大していることは著明である．

上腕三頭筋（TB）は，錘をもあげるときには主働筋の上腕二頭筋（BB）の拮抗筋であるが，初期には，ほとんど放電が見られない．わずかに認められる放電は，上腕二頭筋のそれと時期的には一致し，錘をもちあげる時期に認められる．中期，終期になるにつれて，その放電は増加してくる．撓側手根屈筋（FC）は，錘をもちあげるためには，上腕二頭筋と協働筋となるが，初期においては肘の屈曲と伸展の両期を通じて持続的に放電している．60～65 回では，この放電の振幅が増大するとともに，肘の屈曲の時期に放電が集中する傾向を示している．この傾向は 90～95 回，146

～151回となるにつれて著明になつてくる．このような変化は，上腕二頭筋に見られるものと共通である．

5分間の休息を挿入したあとの，第2回目の試行では，筋力の回復とともに，上記3種の筋の筋電図（放電）は減少し，その1～7回においては，第1回試行の1～6回のものに似てくる．また30～35回，60～65回のものはそれぞれ第一回試行における60～65，90～95回のものに近い．そして，終期90～95回のものは，第1回試行の146～151回のものにきわめてよく似ている．

第7図 ストレインゲージ筋力計による最大筋力の反復測定中に，Shot, Shout を行つたときの最大筋力と主働筋の筋電図．最上段の数字は反復回数，時間記録は0.1秒である．STは最大筋力，BB, TB, FC は上腕二頭筋，上腕三頭筋，および撓側手根屈筋の筋電図，最下段の SHOT, SHOUT はそれぞれピストル音と「かけ声」の時点を示す．



この実験で最も注目すべきことは，腕にかかる荷重が，初期の最大筋力の1/3という固定したものであるにもかゝわらず，筋電図，すなわち運動単位の神経衝撃（放電）が次第に増大するという事実である．さらに，休息により筋力が回復すると，放電が再び減少するということである．

2. ストレインゲージ筋力計を用いた実験

(a) 持久作業の場合の成績

ストレインゲージ筋力計により，上腕屈曲筋の最大筋力を1秒に1回のテンポで出していくとき，最大努力を重ねているにもかかわらず最大筋力は次第に減少してくる．第6図のいちばん上の記録（ST）はこの最大筋力を示すものであり，1～7回のものにくらべ，187～192回のものは明らかに減少している．その後320～326回では，同様の水準を保ち，587～595回では，最大筋力の水準の変動が目立つてくる．そして595回では力尽きている．

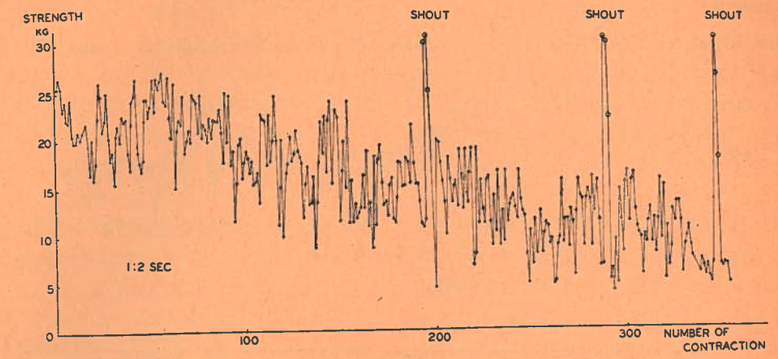
第6図において，それ以下順次に上腕二頭筋(BB)，上腕三頭筋（TB)，撓側手根屈筋(FC)の筋電図が示されている．上腕二頭筋の筋電図は，最大筋力の発揮の時期に集中的にあらわれているが，その振幅は，320～326回の時期に著明な増大を示している．そして587回以後の終期には振幅が減少している．上腕三頭筋（TB）の筋電図はエルゴメーターの場合と異り，上腕二頭筋の活動時期の終了後に著明となる．しかし，上腕二頭筋の活動時期にも上腕三頭筋に放電が見られることもたしかである．587回以後に至つて，上腕三頭筋の放電は上腕二頭筋の活動終了後，すなわち主働筋の脱力の時期に著明となつている．

撓側手根屈筋（FC）の放電は上筋二頭筋(BB)のそれと一致した時期にあらわれる．そして，320～326回にいくらか増大しているが，587回以後では不規則な変動を示している．

(b) shot および shout の場合の成績

ストレインゲージ筋力計において，上腕屈曲筋の最大筋力を2秒に1回のテンポで発揮していくとき，筋力がしだいに減少することは，上述した通りである．そこで筋力が減少しはじめた頃に，被検者に無警告でスタート用ピストルをその背後で発砲したときには，第7図に示す如く，一時的に最大筋力が増大

第8図 最大筋力に及ぼす SHOUT（かけ声）の効果



する．この効果は4秒くらいつづくことが多いが，時には10秒まれには1～2分に及ぶことがあることは，別に報告した[4]．本研究の目的の一つは，この場合の最大筋力の増大に伴つて，筋電図の増大が見られるかどうかということであつた．その結果は，第7図の例で見られるように，Shot に伴う最大筋力の増大は，放電の増大を伴つていることがわかつた．すなわち，548回のあとでピストル音（shot）が与えられたが，約1秒後の最大筋力（549回目の ST）とそれつぐ最大筋力(550回目の ST）は増大し，上腕二頭筋(BB)の放電はその前のものにくらべて大きい．

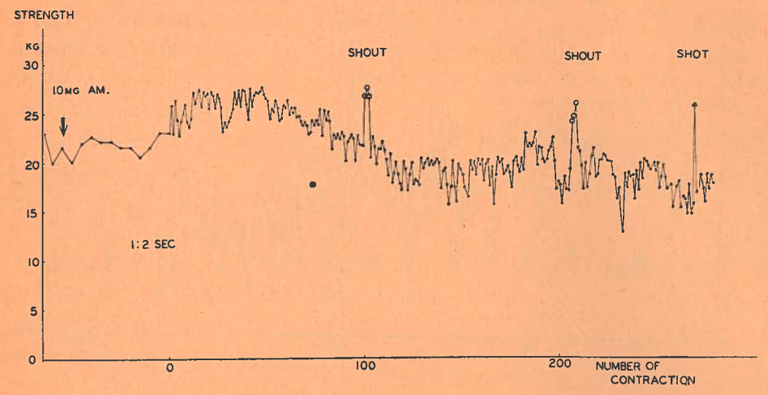
さらにその後の経過において，被検者が自発的な「かけ声」(shout）をかけながら，最大筋力を発揮することを試みた．その結果は，第7図の673回，674回に見られるように，最大筋力（ST）は増大し，しかも上腕二頭筋(BB）と撓側手根屈筋（FC）の筋電図は増大している．

第8図は，最大筋力をストレインゲージ筋力計で測定しながら，shout を与えたときの最大筋力の消長をグラフにあらわしたものであり，ストレインゲージの振れの大きさが換算表により，kg にかきかえられている．9個の白丸は shout と共に出した筋力で，相当に筋力が低下してきたときでも，shout の効果は著明である．しかも，200回，および300回ころでも shout による最大筋力の上昇した水準は，作業の初期の水準を上回るという著しい増大を示していることは注目さるべきである．

(c) Amphetamine sulshate を投与した場合

健康成人10名に10～16mg の Amphetamine sulphate（Zedrin 武田）を投与したとき，一般に最大筋力の変異が減少することが認められたが，中には投与後30～40分で明らかな最大筋力の増大を示すものがあつた．それらのなかの1例を示すと第9図のようである．すなわち，この被検者は Amphetamine sulphate を 10mg 径口的に服用したあと，5分毎に最大筋力を発揮したが，50分後からは2秒に1回のテンポで行つた．最大筋力は約50分後から増大しているが，約80回目のころから減少しはじめている．そして，100回目くらいのところで被検者の自発的な3回の「かけ声」とともに，最大筋力は増大し，Amphetamine 服用後の最大筋力が最高水準を示した時期の値に近づいている．さらに，時間の経過とともに最大筋力は低下していくが，200回をこえたところで，再び3回の「かけ声」をかけたところ，最大筋力は最高水準に近く回復した．さ

第 9 図 最大筋力に及ぼす Amphetamine, SHOUT, SHOT の効果



らに，ピストル音 (shot) を与えたが，このときも最大筋力は最高水準に近く回復した．

この実験においては，Amphetamine 服用後の最大筋力増大の時期には，主働筋の筋電図には認めるほどの増大はなかつた． しかし shot, shout の場合には， 前記の実験の場合と同様に筋電図の増大がある．

IV 論　　議

さきに，猪飼と Arthur H Steinhaus[4] とは，最大筋力の生理的限界と，心理的限界を，量的に取扱う試みをし，その可能性を示した．本研究は，それにつづき，筋電図を用い，筋への運動単位の神経衝撃を記録し，量的な取扱いの他の分野を開拓しようとしたものである．

筋が収縮して発生する力というものは，終局的には筋の横断面積の函数であり，且つまたその組織の生理的状態の函数である．しかし，実際に発揮される力は生理的因子の変動以上に大きい範囲の変動を示すものである．また，筋やこれを支配する神経組織のうちで，筋と末梢神経とは比較的安定な状態を保持するものであると考えられるので，通常見られるような筋力の変動，ならびに本実験において見られるような広汎な変動は中枢神経系統によるものであるといえよう．したがつて，最大筋力を規定する生理的限界というのは，筋の横断面積，およびその組織の生理的状態によつて一義的にきまるものを指す．これにたいして，心理的限界というものは，中枢神経系統の活動状態は元来，生理的として取扱うことができるので，あえて「心理的」という用語を用いる必要はないともいえるが，最大努力で体力を発揮するという人間の行動に関しては，民族の歴史や個人の体験などの生活的な因子により，影響を受けると考えられるので，あえて心理的という用語を用いたわけである[7]．

ここにおいて，本実験において行つた，腕エルゴメーターの場合を考察しよう．第 3 図に見られるように，上腕二頭筋 (BB) の放電は回を重ねるにつれて増大している．これは明らかに，筋活動に参加する運動単位の数，および運動単位の神経衝撃の頻度が増加することを示している．このことは，さらに大脳皮質運動領の興奮水準の上昇を意味するものである．しかも，この場合に注意するべきことは，もちあげる荷重の重さは，初めも終りもつねに一定であるということである．すなわち，上腕屈曲筋，とくに上腕二頭筋は初めも終りもつねに同一の物理的な仕事をしているにもかかわらず，終りに近づくにつれて，運動単位，ないし大脳皮質運動領の興奮状態が高まつてくるということである．これは，回を重ねるにつれて，筋線維の張力発生が減退するので，一定の筋力を出すためには，より多くの運動単位の参加，衝撃の増加を必要とするといえる．そして，このためには大脳皮質運動領の運動細胞の数あるいは，その興奮水準をあげなくてはならない．これは，いいかえれば，心理的限界を上昇させることになる．エルゴメーター作業をつづけるうちに，内省的には非常に努力感を伴うようになるが，これが筋電図の増大にほぼ比例している．この場合に，筋紡錘を中心として知覚神系を介しての感覚，および，Gamma 線維を介しての反射系を考慮の外におくことはできないであろう．筋にかかる荷重はつねに同一であるという点では，筋紡錘の興奮は同一であるともいもいえるが，錘りをもちあげるための筋線維の収縮が短時間に完全におきにくくなるために，包内線維のひきのばされ方が強くなるということが考えられる．この結果は，筋紡錘の興奮を増加させ，知覚神経を介して間脳，ないし大脳皮質知覚領における興奮水準をたかめるとともに，Gamma[9] 系の興奮水準をたかめることになる．

間脳における興奮水準の上昇は，新たな神経衝撃を大脳皮質運動領へ追加することになるが，これは Penfield[10] のいう随意運動への中枢脳系からの調整である．別の表現を用いれば，「がんばり」のあらわれであり，ここにいう「心理的限界」の上昇である．このような機構により，主働筋への神経衝撃の増大を理解することができる．152 回目は完全な錘のもちあげができないわけで，ここで作業を中断したわけであるが，5 分の休息ののち，筋の収縮力が回復して，再び作業をつづけることができるようになるとともに，主働筋の神経衝撃が再び減少していることは筋線維の張力が回復し，収縮が短時間に完全に行われるようになるため，筋紡錘からの神経衝撃，ひいては，大脳皮質運動領からの神経衝撃の減少がおこると考えられる．そして終りに近づくにつれて，第 1 回試行のときと同様に神経衝撃の増大が見られるわけであるが，この機構については，第 1 回試行のときと同様と考えられる．

この場合に，共働筋 (FC)，のみならず拮抗筋 (TB) にも放電の増加が伴うことは，大脳皮質運動領の興奮が，必ずしも厳密な局所性をもつたものでないことを意味しているとともに，主働筋への Gamma 系を介しての反射的調整よりも，視床下をふくむ上位中枢を介しての調整を考えさせるものである[2]．

ここで注意すべきことは，このような実験条件では筋力と筋電図の放電量とは比例しないということである． さらに．テストの実施上からいえば，主働筋の筋電図にこのような放電量の増加がなければ，ほんとうに「がんばつた」とはいえないことになる．このように筋電図は「がんばり」の指標となる．

つぎに，ストレインゲージ筋力計による上腕屈曲筋の最大筋力測定の場合について考察する．これは，上記のエルゴメーターの場合と異り，つねに最大筋力を出していることであり，したがつてその筋力はつねに毎回変動するものである．この場合の主働筋の放電を見ると，はじめのうちは最大筋力の低下にも拘らず，筋の放電の大きさはかわらないが，300 回の反復の時期にいたると，筋力の減少にもかかわらず，筋の放電は増加してくる．この筋の放電の増加は，前記のエルゴメーターの場合と同様に，大脳皮質運動領の活動水準の上昇と考えられるが，これをひきおこす知覚系の機構には多少のちがいがあるはずである．すなわち，エルゴメーターの場合には，荷重が一定に与えられているので，知覚系はこれにしたがつて作動するはずであるが，ストレインゲージ筋力計では知覚系を作動させるも

のは，自発的に出した筋力，ないし筋の張力である．最大筋力を出したときの知覚は，ストレインゲージを貼布した木の棒からうける圧によつて生ずるものであり，筋力が低下したときには，圧の知覚の低下がおこるであろう．圧の知覚の低下は自己の筋力の低下を意識させる結果となり，更に強い力を出そうとする努力を誘起するはずである．したがつて，この場合の筋放電の増大は，Gamma 系を介しての反射的のものというより，上位中枢を介する調整と考えられる．これはまた，中枢脳系からの随意運動の調整の機構をふくみ，いわゆる「心理的限界」を上昇させるということの生理学的内容である．さらにすすんで，587 回以後，力尽きる頃には，筋の放電は減少してくる．これは「心理的限界」の低下する状態である．

この実験でも，筋力と筋電図，ないし筋の放電量との間には，簡単な比例関係はないことが注目される．

第三に考察すべきことは，ShotおよびShout実験のことである．ストレインゲージ筋力計で最大筋力を2秒に1回のテンポで出していくとき回を重ねるにつれて筋力は低下してくるが，ピストル音につづく試行では最大筋力が増大し，第7図において見るように，このとき筋の放電量の増加がある．これは音の刺激が内耳から大脳へはいり，大脳皮質運動領の活動水準をたかめるようにはたらきかけるものであろう．しかし，Shot と同時に放電がおきるのではないので，いわゆる「びつくり反射」によるものではない．音により大脳内に生じた旧皮質の賦活作用が，間接的に大脳新皮質の運動系の活動水準をたかめるものと推定される[12]．猪飼と Steinhaus[4,7] とは，さきに，Shot による筋力増大は，「大脳に存在する内制止を，音という刺激による外制止により脱制止すること」であると推測したが，筋電図の記録だけではこの推測を検討するまでには至らない．ただ，明らかになつたことは，Shot につづく筋収縮が，運動単位のより高い水準の興奮によつて行われるようになるということであり，この意味で心理的水準の上昇をきたしたものということはできる．

Shout により筋の放電の増大とともに最大筋力が増大することもと，Shot と同様に解することができよう．Shot は他動的のものであり，Shout は自発的なものであるが，その作用機構については同様のものと考えられる．

最後に考察すべきものは，Amphetamine Sulphate 投与の場合である．Amphetamine を用いて，筋力や作業能力をしらべた業績はいくらかある．Alles と Feigen[1] は Amphetamine を 20～40mg 使用し，作業能力の増大することをみとめ，これを中枢のシナプスに作用するものとしている．Spengler は Amphetamine を用い，自転車エルゴメーターで持久力をしらべ，持久力の向上を認めている．Smith と Beecher[10] は体重 70kg にたいし，14mg の Amphetamine を服用させ，重量挙選手の 85% に成績の向上を見たとしているが，被検者がすでに競争意識を高揚させているときには，薬物の効果は少いと述べているのは注目すべきものである．

Karpovich[8] は 54 人の被検者について，Amphetamine の効果をしらべ，水泳，トラック走，トレッドミル走などの成績には一義的な成績は得られないことを述べている．

猪飼と Steinhaus[4] とは，30mg の Amphetamine を服用させ，25 分間経過したところで最大筋力が増大しはじめ，その後 30 分に及んで測定した範囲内では，対照にたいし 1.35% の増大を示すことを認め，その増大は 5% の危険率で有意なことを報告した．そして，Alcohol や Adrenaline の効果と同様に，この薬物によつて解発された大脳の脱制止が筋力増大の原因であると考察した．

本研究においては，Amphetamine の服用後に，第9図にその1例を示す如く，最大筋力の増大を認めたが，主働筋の筋放電には著しい増大は認められなかつたので，Amphetamine による筋力の増大と運動単位の活動水準，ないし大脳皮質運動領の活動水準との関連については，今直ちに立入つた論議をすることはできない．

ただ，これにつづく反復作業において，筋力が低下してきたときにおける，Shout, Shot では筋放電の増大と共に最大筋力の増大が認められることは，上述の場合と同様である．ここで注目したいのは，Amphetamine 服用後に上昇した最大筋力の水準が，Shot や Shout によつて上昇した最大筋力の水準とほとんど同一の水準であるということである．これは，いかなる方法によつてたかめられても，最大筋力の最高水準は同一であるということを示唆するものである．これは心理的限界の上限を示すものともいえよう．

V 結 論

腕エルゴメーター，およびストレインゲージ筋力計を用い，持久力および最大筋力を以下の諸種の条件のもとに測定する経過において，主働筋および拮抗筋からの筋電図を記録し，諸種の結果を，体力の生理的限界および心理的限界という観点から考察した．

1. 腕エルメーター実験．腕エルゴメーターには腕屈曲筋の最大筋力の 1/3 の荷重をかけ，1秒に1回のテンポで錘をもちあげ，疲労困憊にいたつて終了した．主働筋，とくに上腕二頭筋の筋電図は反復を重ねるにつれて，その電圧及び頻度を増す．これは心理的限界の上昇により筋線維の疲労を代償するものと考えられる．

2. ストレインゲージ筋力計による実験．ストレインゲージ筋力計を用い，1秒に1回のテンポで，上腕屈曲筋の最大筋力をくりかえし発揮して疲労困憊にいたる経過において，主働筋の筋電図を記録した．主働筋，とくに上腕二頭筋の筋電図は作業の終りの時期に著明な増大を示した．これは筋線維の疲労に伴い，心理的限界が上昇したことを示すものと考えられる．

3. Shot および shout 実験．ストレインゲージ筋力計を用い，2秒に1回のテンポで最大筋力をくいかえし発揮し，筋力が低下を示しはじめた時期に Shot, および Shout を与えると最大筋力は増大するが，このときに主働筋の筋電図は電圧及び頻度の増大が見られる．これらも音の刺激により心理的限界の上昇したことを示す．

4. Amphetamine 実験．Amphetamine sulphate を服用したときの最大筋力の増大時期には，主働筋の筋電図の増大は著明でない．Amphetamine 服用後の最大筋力の増大の水準はその後の Shot および Shout によつて増大した最大筋力の水準とほぼ同一となる．これらは，異る方法によつてあげられたものであつても，心理的水準の上限は一定であることを示す．

本研究の実施にさいし，瀬畑昇，寺岡暉，矢部京之助の諸君が与えられた助力を謝す．またエルゴメーター等の試作は，文部省科学研究費（班長，白井伊三郎教授）の援助により，また筋電図学的測定に関しては，体力医学会を介して野球博物館の援助によつて行われた．ここに感謝の意を表する次第である．

なお，本研究は，1961 年7月 New Delhi, India において開催された ICHPER, WCOTP において報告されたものである．

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An Electromyographic Study on the Physiological and Psychological Limits of Human Strength

Michio Ikai and Kihachi Ishii;
The University of Tokyo

The muscular endurance has been tested on the arm ergometer and the straingauge tensiometer together with recording of the electromyograms from the acting muscles. The test consisted of four different procedures and the results were discussed from view point of physiological and psychological limits of performance.

1. The subject contracted the arm flexor on the ergometer with the load of 1/3 of the maximal strength once a second until an exhaution. It was found that electromyograms of the flexor muscles were gradually increased in voltage and frequency in later stage of work.

2. The subject contracted the arm flexor isometrically against the horizontal bar attached with a straingauge apparatus once two seconds with his maximal effort until an exhaustion. It was found that the electomyograms of the arm flexors were increased remarkably in later stage together with an apparently decreased strength.

3. In later stage of the endurance test on the straingauge tensiometer, the subject was given a sound of "shot" of a starting pistol or a sound of "shout" by himself. It was found that the maximal strength recovered up to the initial level of the stregth and sometimes over the initial level of the strength together with an increase of nervous discharge to the arm flexors.

4. The maximal strength was measured once two seconds after the administration of Amphetamine Sulphate until an almost exhaustion on the same subject. It was worthy to note that the elevated level of the maximal strength after the administration of the drug was almost same as that of "shout".

These findings appear to be an additional support of the thesis suggested by Michio Ikai and Arthur H. Steinhaus that in every voluntarily executed, all-out maximal effort, psychologic rather than physiologicl factors determine the limits of performance.

Dr. Wiener
with compliments
Michio Ikai

PHYSICAL FITNESS STUDIES IN JAPAN

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PHYSICAL FITNESS STUDIES IN JAPAN

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Physical Fitness Studies in Japan

While visiting Chicago, the author was asked to speak on the physical fitness of Japanese by Professor. Arthur H Steinhaus at George Williams College. The audience, however, was limited, and since then the author often wanted to get a good opportunity to present some of the results of physical fitness tests as well as some topics of researches on this matter in published form. It is a great pleasure for the author here to show physical fitness status in Japan to the friends overseas in our field of education.

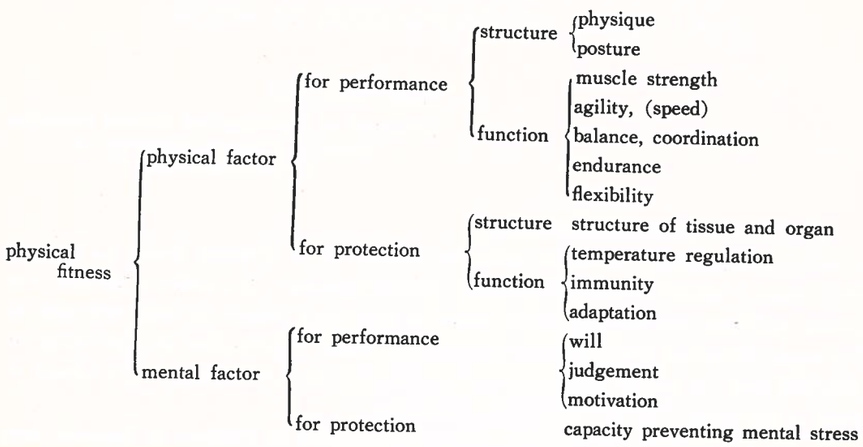
As presented in another paper in this volume, measurement of physique of Japanese boys and girls at school has been conducted with regular intervals since sixty or more years ago throughout the country under the direction of the Ministry of Education. These records are available to follow some change of physique of Japanese children during half a century or more. As to the motor ability or physical performance, however, very little is available to follow some possible change with advancing years due to lack of uniformity of the test.

For recent fifteen years, physical fitness has been emphasised to study with a new concept under some fruitful influences from abroad. The Research Committee of the Japanese Society of Physical Education has focused their interest to devise a new physical fitness test battery for Japanese children. The test consisted of measurement of muscular strength, speed, agility, balance, flexibility and endurance and so forth. The test has been carried out on boys and girls at high school and college students. The results obtained by this test gave some useful suggestions to teachers. On the other hand, motor performance test, including running, jumping and throwing and others has been conducted with intervals of two or three years under the direction of the Ministry of Education. The results of these tests illustrate the degree of improvement in physical fitness of Japanese young people after the War.

The concept of physical fitness

The concept of physical fitness was under discussion by members of this society at the research Committee for some years since 1950. The next table is one of the results of study of physical fitness eoncept presented by members including Professor K. Hukuda and the present author.

Concerning the test, physical fitness can be measured with respect to motor performance such as running, jumping and throwing as described above. These factors may be considered as the basic forms of human behavior related to the structure of the human body. It could be called the prototype of human movement. In other words, these patterns of movement depend upon the special neuro-muscular coordination of the human body. On the other hand,



physical fitness can be measured in terms of energy deliberation such as strength, speed, and endurance. About thirty five years ago, A.V. Hill extended a fruitful discussion on speed, strength and endurance as well as jumping, throwing and running in his original book "Living Machinery." Recently an interesting paper by D. Mateev (11) on three qualities such as strength, speed and endurance in the Bulletin of F.I.E.P. Referring to works in this country and abroad, some topics of measurements and researches of physical fitness are presented here.

Motor performance of boys and girls

The test which was carried out under the administration of the Ministry of Education since 1949 showed that Japanese boys and girls made much progress in physique and motor perfo-rmance year by year after the end of the War. The present situation of physical fitness of Japanese young people is illustrated by some of the results of the test in 1959 as listed here (12). Amounting to 21,797 boys, 22,578 girls selected statistically at random from 91 elementary, 43 junior and 41 senior high sohools in 26 prefectures out of 46 of all over the country were subjected to the test. They were from age 8 to age 17. The items of measurements were running of 50 meters, (100 meters for above age 15), standing broad jump, vertical jump, throwing a soft ball, chinning (the number of flexions on the arm in boys, the duration of flexion of the arm in girls), agility (Burpee test), and swimming ability as well as body height, body weight.

1) ***Running***. The time of 50 meters running was plotted against age as in Fig. 1. The running ability was developed with age in boys and girls,while the improvement was retarded after age 12 in girls. The speed of running in relation to the body height was plotted with logarithmic scale as shown in Fig. 2. It is worth while to note that the relation between the speed and height can be presented by two straight lines in boys, and one in girls. This means that boys taller than 155cm show an additional increase, while girls show a tendency to stagnate. The body height of 155cm in boys corresponded to age 14. As was suggested by E. Asmussen and KR. Heeboll-Nielsen, this phenomenon could be related to the function of sexual hormone and the characteristics of maturity in both sexes. This relation between speed and height can be exrpessed by the formula,

$$log\ y = log\ b + \alpha log\ x$$

or

$$y = bx^{\alpha},$$

where x is body height, y is speed of running and b and α are constants. The value shows a tendency of improvement ot motor performance with height. As to the running of 50 meters, the value of the constant α was calculated by Morishita: $\alpha = 0.884$ in boys shorter than 155cm, $\alpha = 1.325$ in boys taller than 155cm, and $\alpha = 0.406$ in girls. According to the data presented by E. Asmussen, the value of the constant α was 0.766 in boys and 0.198 in girls in Denmark. It was found that the running speed was improved with increasing height more in Japanese boys and girls than in Danish.

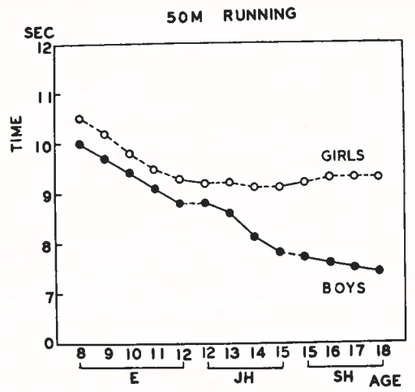


Fig. 1. Time of 50 meters running in relation to age.
E: elmentary school, JH: junior high, SH: senior high school students. 1959, Ministry of Education.

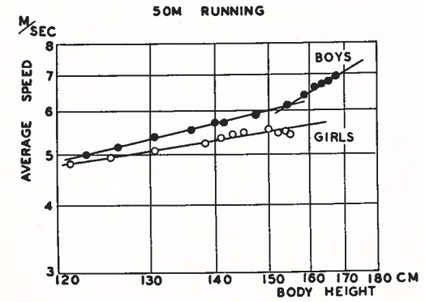


Fig. 2. Speed of 50 meters running in relation to body height.
Modified by Ikai and Morishita.

2) ***Throwing***. The distance of throwing of soft-ball, weighing 170 grams and 30.16cm in circumference, was measured on the same subjects as in running. The distance of throwing was plotted against the body height in logarithmic scale as in Fig. 3. The values of the constants were calculated as follows: $\alpha = 3.670$ in boys shorter than 155cm, $\alpha = 4.290$ in boys taller than 155cm, and $\alpha = 3.265$ in girls.

3) ***Jumping***. The jumping ability was tested by the distance of standing broad jump and vertical jump. The results were shown in Fig. 5, and Fig. 6. The values of α were calculated as follows: for broad jump $\alpha = 1.394$ in boys shorter than 155cm, $\alpha = 2.325$ in boys taller than 155cm, and $\alpha = 1.094$ in girls. For vertical jump $\alpha = 2.263$ in boys shorter than 155cm, $\alpha = 4.126$ in boys taller than 155cm, and $\alpha = 2.243$ in girls.

It was found by these tests that Japanese boys and girls, ranging from age 8 to 17, surpassed Americans at every age level in standing broad jump, vertical jump, and soft ball throwing, referring to the results presented by A. Espenshade (4). The speed of running was almost

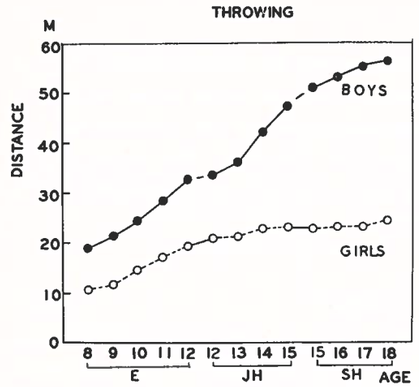


Fig. 3. Distance of throwing of soft ball in relation to age. Ministry of Education, 1959.

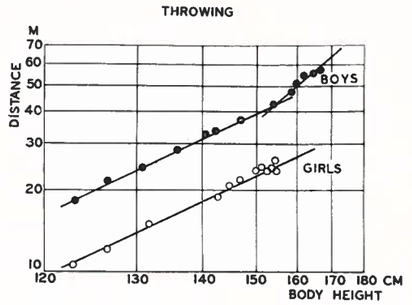


Fig. 4. Distance of throwing of soft ball in relation to body height. Modified by Ikai.

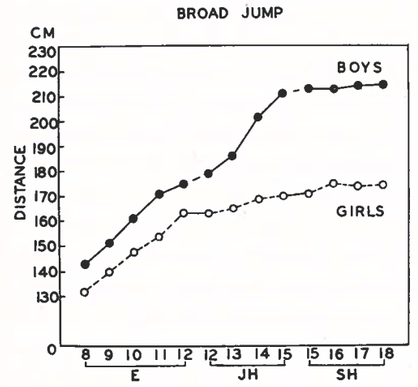


Fig. 5. Distance of broad jump in relation to age. Ministry of Education, 1959.

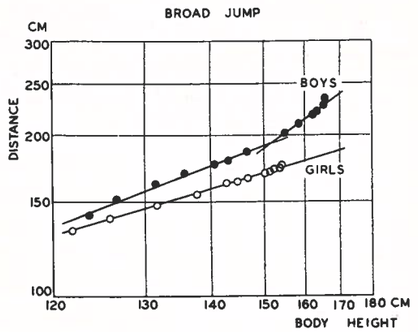


Fig. 6. Distance of braod jump in relation to body height. Modified by Ikai.

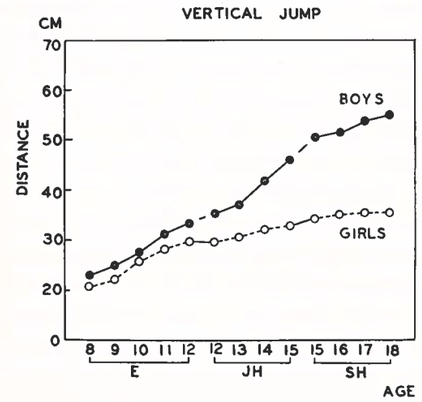


Fig. 7. Height of vertical jump in relation to age. Ministry of Education, 1959.

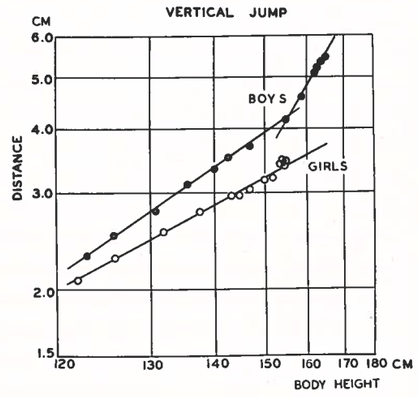


Fig. 8. Distance of vertical jump in relation to body height.

the same in both kinds of children.

On the other hand, it was also found that motor performance in relation to the body height was higher in Japanese than Danish, referring to the data presented by E. Asmussen (1, 2).

These results should be criticized in connection with other similar result conducted by AAHPER National Fitness Test Battery (14). Further studies should be carried out to know how much of fitness people need for their happiness, as was suggested in a paper by P.V. Karpovich (13).

Characteristics of strength, speed and endurance.

Physical fitness can be discussed from the following viewpoint.

1) *Strength.* The strength is a quality of physical fitness which delivers a mechanical energy, while the muscle contracts. Now it can be called muscular strength. The muscular strength has been measured with grip dynamometer, back dynamometer on school children. However, further study to know how to use the results of measurement of muscle strength is needed.

Regarding the training of muscle strenngth, progressive resistance exercise has been emphasised in addition to ordinary weight training for improvement of physical fitness in general of people. In Japan, progressive resistance exercise is not at all new and quite familiar to the people for a long time. Because Japanese Sumo wrestlers have been trained by resistance exercise since hundreds years ago. They used to practice to push against the standing pole with both hands extending their legs with the maximum effort, and more often against the opponent each other. It is noteworthy to know that they do not spend much time for their muscle training and they take a sufficient time to rest. It is believed that they had found the principle for muscle training from their age-old experiences. Recent advance of knowledge on muscle training afforded a scientific basis to this training (5).

For good performance of muscle strength, one should learn how to concentrate the discharge

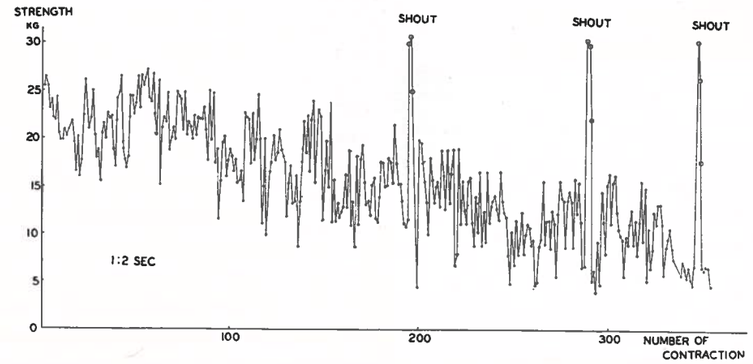


Fig. 9. A fatigue curve of the muscular strength of the arm flexor and the effect of "shout" on the performance. The contraction was carried out once two seconds on the arm ergometer the maximal strength of the arm flexor (Ikai and Ishii)

of the nerve impulse to the corresponding muscles. In other Japanese national sports such as Judo and Kendo, i.e. Japanese fencing, one used to attack his opponent with a "shout". With an interest to know some mechanism of effect of "shout" on human performance, the present author conducted a research with A. H Steinhaus in Chicago in 1959. As reported elsewhere, it was confirmed that a remarkable increase of muscle strength with shout (Fig. 9). The same effect was found in hypnosis and after a big noise such as "shot". The mechanism governing these phenomena was discussed from viewpoint of disinhibition of the higher center of the central nervous system (7).

The present author has extended his research with recording electromyograms from corresponding muscles together with straingauge recorder of strength during and after the "shout" and "shot". It was confirmed that nerve impulses were increased in voltage at the working muscles with shout and immediately after the shot (Fig. 10). It is supposed that most muscle fibers could join the action due to the simultaneous firing of all the motor units with shout and shot. Under such a condition the subject can easily concentrate his energy to do his

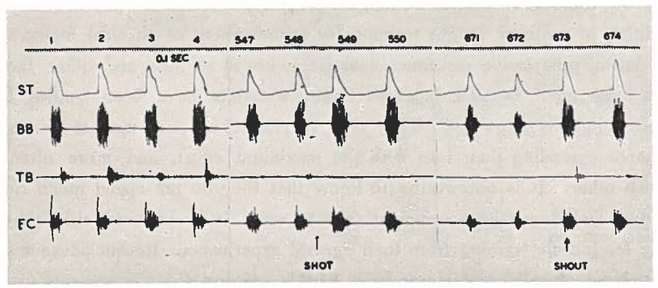


Fig. 10. Effect of Shout and Shot upon the motor units discharge of the arm as well as the maximal strength of the arm flexor. The number of contraction was indicated on the top, ST was the maximal strength, BB motor unit discharge of m. biceps brachii (arm flexor), TB m. triceps brachii (arm extensor), and FC m. flexor carpi radialis (hand flexor). Arrows show the time of Shot and Shout (Ikai and Ishii)

Fig. 11. Arrangement of testing the maximal strength of the arm flexor with the straingauge tensiometer (Ikai and Ishii)

work. In another experiment conducted by the author, the subject contracted his arm flexor isometrically against the horizontal bar attached to straingauge recorder once in two seconds with the maximal effort to exhaustion (Fig. 11). The electromyograms were recorded from m. biceps brachii, m. triceps brachii and m. flexor carpi radialis (Fig. 12). It was found that the discharge of motor units to the flexor muscle was increased at a stage when the maximal strength was decreased by twenty per cent of the initial level of the strength. It was supposed

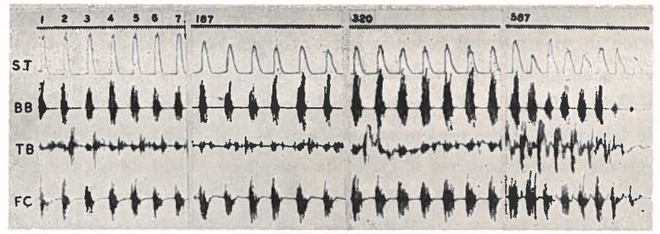


Fig. 12. Electromyographic record of the arm flexor (m. biceps brachii-B.B.), Arm extensor (m. triceps brachii-T.B.) and hand flexor (m. flexor carpi radialis-F.C.) together with the record of the muscle strength of the arm flexor with straingauge ergometer. The number on the top shows the number of contraction. With advancing time, the muscle strength declines gradually, while the motor units discharge is increased on the contrary. At the final stage, both activities decline at all. (Ikai and Ishii)

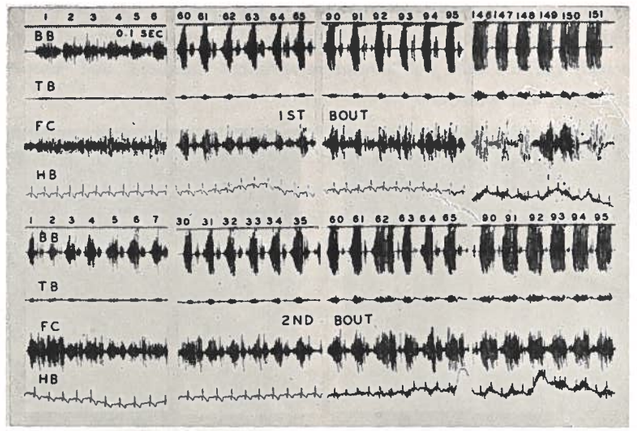


Fig. 13. Electromyographic record of the arm flexor, m. biceps brachii, during the work on the ergometer with the load of 1/3 of the maximal strength of the arm flexor. together with recording of electromyograms from m. triceps brachii, and m. flexor carpi radialis as well as the electrocardiogram from the chest. The number of contraction was indicated on the top of each series of the test, the first bout and the second bout. After 5 minutes rest of the first bout, the second bout started again to exhaustion. It is found that electromyographic record of the arm flexor was incresed in advancing time against the constant weight of the load on the ergometer. (Ikai and Ishii)

that that psychological limit was elevated close to the physiological limit (See Fig. 13).

2) *Speed.* The speed of the movement of parts of the body depends on the neuro-muscular coordination. As for the speed of running of a certain distance, circulo-respiratory functions join the activity in addition to the neuro-muscular functions. As a topic of the research in this field, reaction time study is presented here. Although many researches have been done in reaction time with the response of the hand to the stimulus, it would be more useful to measure the reaction time of the movement of the body as a whole from view point of sports

activity as well as safety education. The vertical jump reaction time method has been devised by T.K. Cureton for this purpose (3). During staying in Japan, Dr. T.K. Cureton expressed his opinion at a meeting that the vertical reaction time measurement would be useful for screening the ability of sprint. For an additional purpose, the body reaction time recorder was devised at the laboratory of the present author (Fig. 14, 15). The platform attached to the straingauge recorder was constructed to trace the change of weight during the response of the body to the stimulus. This apparatus resembles that of L. Lauru (10). The record of body reaction time with this apparatus consists of two parts, one is a factor due to the speed of conduction in the nervous system and the other is a factor due to the speed of muscle contraction. In Fig. 16, a sound stimulus was recorded at a signal 0, and the beginning of muscle contraction was recorded at A, while the time of leaving the platform at B. In this figure, the duration OA is the time for travel of nerve impulse from the receptor to the muscle, while the duration AB is the time for contraction of the muscle. For convenience the former may be called the nerve reaction time and the latter the muscle contraction time. It was found that the body reaction time was shorter in sprinters, hurdlers, and jumpers than shot putters, weight lifters, and wrestlers.

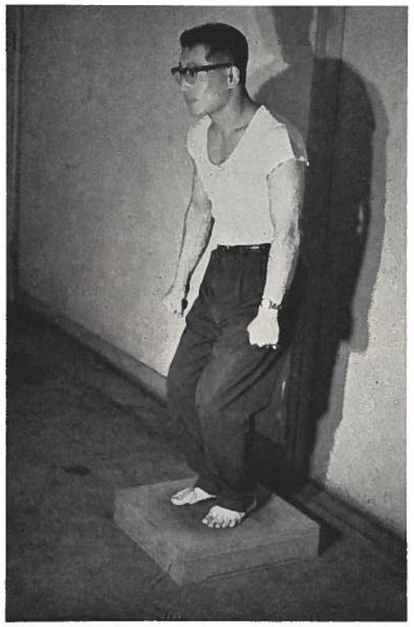


Fig. 14. A subject who is ready to response to a stimulus of sound or light on the platform attached to the straingauge recorder. (Ikai, Asami and Shibayama)

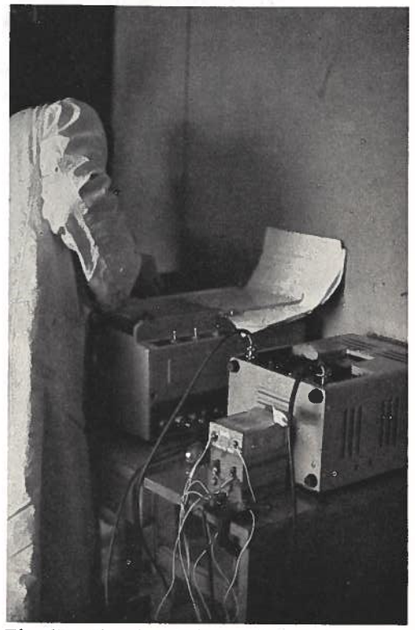


Fig. 15. The electrical recording equipment for total body reaction time connected with the platform in the next room. (Ikai, Asami and Shibayama)

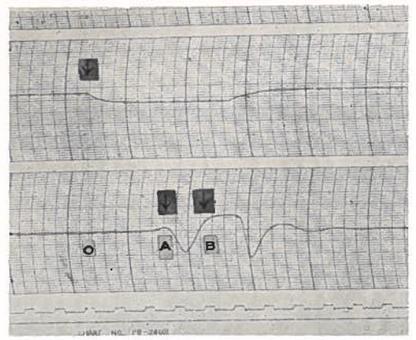


Fig. 16. A record of Body Reaction Time to a sound stimulus. The middle curve shows a record of reaction time, the upper the signal of sound stmulus, the lower the time mark of 0.1sec. (Ikai, Asami and Shibayama)

Table 1. Total Body Reaction Time

Subject (Number)	Conduction time in sec.	Contraction time in sec.	Body reaction time in sec.
	boys		
Untrained (40)	0.210±0.031*	0.155±0.016	0.365±0.039
Trained (48)	0.166±0.023	0.142±0.019	0.308±0.035
Top-bracket athletes (29)	0.199±0.033	0.125±0.013	0.324±0.042
	girls		
Untrained (30)	0.211±0.023	0.174±0.021	0.385±0.036
Trained (15)	0.164±0.016	0.143±0.013	0.307±0.021
Top-bracket athletes (11)	0.200±0.021	0.139±0.011	0.339±0.026

* Mean±standard deviation

After the training, the body reaction time was decreased to some extent mainly due to shortening of the contraction time of the muscle. Some of the results were shown in table 1.

Another factor governing the speed is the reciprocal innervation to the extremities of the human body. The rapid repetitive movement of the hands or legs were tested as tapping or stepping ability. These functions are closely related to reflexes involving the brain stem, cerebellum as well as the feed-back system of muscle spindle. After an electrsmyographic study of tapping test, it was found that deteriolation of this rapid movement appeared due to lack of rapid alternation of impulses to the agonist and the antagonist of the arm. It is supposed that in the first stage of fatigue the timing and spacing of nerve impulses to the corresponding muscles might be disturbed and therefore the impulses arrived at the flexor as well as the extensor muscles at the same time, in the second stage some of the impulses failed to reach the corresponding muscles. This means the disorientation of the pattern of excitation of the motor area of the brain. It might be of interest to discuss these phenomena as a protective inhibition of the central nervous system.

The stepping is more closely related to natural behavior such as running. The subject stepped as fast as he could during ten seconds on the platform connected with the straingauge recorder. The average number of stepping for ten seconds in trained and untrained college students.

Table 2. The Number of Stepping per 10 seconds.

Bays	Untrained	98.0±11.7*
	Trained	112.0±10.7
Cirls	Untrained	93.0±12.1
	Trained	101.0±11.1

* Mean±standard deviation

3) *Endurance.* The endurance is usually classified into strength endurance and speed endurance. On the other hand, endurance may be discussed as muscular endurance and general endurance, while general endurance

involves to a large extent cardiovascular and respiratory functions. Some of the results obtained by the tests on muscular endurance as well as general endurance are prasented here as follows:

a) ***Muscular endurance.*** For measurement of muscular endurance, the arm ergometer has been used by many researchers in this country as well as abroad. At the University of Tokyo, Ishiko, T (9) conducted a work with his new forearm ergometer which could be applied to record phasic or static muscular work practically indepenently from each other. It was confirmed that, for both types of work, the following equation was applicable to the relation between the load and the endurance time:

$$log\ t = a\,log\ N + b,$$

where t is the endurance time, N the load, a and b are constants. He stated that this relation might correspond to that of Gross-Lordermann and Müller for muscular work with the bicycle ergometer.

The present author have been working with a newly devised simple ergometer useful for arm and leg. This ergometer is designed to apply the load always rectangular to the axis of the forearm while the angle of the elbow joint changes during the work. One third of the maximal strength of the arm flexor was chosen for the load. The same arrangement was used for the endurance test of the leg. This work with ergometer by the author was started in 1959 when the author spent several weeks at the Physiological Laboratory of Springfield College with Dr. P.V. Karpovich. This ergometer, as shown in Fig. 17, is much reasonable to keep the mechanical condition constant during the work like the ergometer used by I. Fisher. Another important point of this method adopted by the present author was that the load was chosen in terms of the maximal strength of the subject. The load namely may be changed from 1/3 to 1/2, 2/3 or 1/4 of the maximal strength. It is worth while to note that the number of muscular contraction on the ergometer with the load once a second is almost the same in old and young as well as boys and girls. The number of contraction of the arm flexor ranged approximately from 60 to 70. More interesting to know that the number of contraction of the leg extensor on the ergometer, with a load of 1/3 of the maximal strength of the leg extensor, was also about 60. In subjects specially trained for long distance running, the number of contraction of the leg was incresed by five times or more compared with the average.

Fig. 17. A high school student on the test of muscular endurance with the arm ergometer. (Ikai and Ishii)

After the daily training on the arm ergometer with the load of 1/3 of the maximal strength, the number of the contraction of the arm flexor was increased from 60~70 to more than 150 after four weeks in elementary and high school boys. It might be important to recognize

some individual differences of training effect on muscular endurance in spite of an identical schedule of training.

b) ***Cardio-respiratory endurance.***

On the other hand, cardio-respiratory adjustment to the endurable work was under study for some years on the treadmill at University of Tokyo (Fig. 18). The research project with this equipment under the help of Ministry of Education has been concentrated to settle a prescription of exercise with respect to age and sex for improvement of physical fitness, particularly endurance in general, of Japanese people. This work does not limit the application to athleticism. The main purpose of this work should be for the improvement of physical fitness of ordinary people in this country. The measurement of all out running time on the treadmill with 8.6% upward slope at three kinds of speed: 160m/min., 180m/min. and 200m/min. was on elementary, junior high school boys and girls, while 160m/min was replaced by 220m/min. on senior high school students. On athletes the speed of 200, 220 and 240m/min. was applied for the treadmill endurance time test. The result will be published in the next opportunity by the present author and collaborators at the University of Tokyo. The author is happy to cite an interesting experience together with a teacher of elementary school on the favourable effect of one month treadmill running upon the general improvement of physical fitness of fifth grade boys. After training of 5 minutes running at speed of 180m/min. three times a week during 4 weeks, the running time on the treadmill was doubled in these elementary school boys.

Fig. 18. The motor driven treadmill working at the Physiologic Research Laboratory in Physical Education of University of Tokyo with simultaneous recording electrocardiogram, electromyogram, respiratory movement, lung ventilation. oxygen consumption and body temperature.

To analyse the mechanism of improvement of the endurance running time on the treadmill, University students served as the subjects. After training of 5 minutes running at speed of

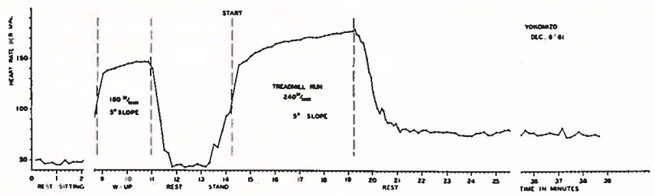


Fig. 19. An example of recores of the heart rate before, during and after the running on the treadmill at speed of 240m/min. (Ikai, Yoshizawa, and Nakagawa)

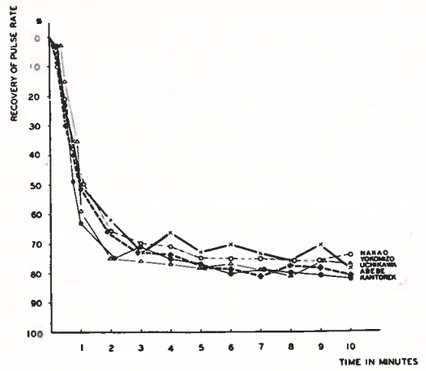


Fig. 20. Comparative representation of recovery of the heart rate after the running on the treadmill at speed of 240m/min with the slope of 8.6%. The ordinate shows the recovery with the following index:
Recovery index of the heart rate

$$= \frac{\text{Maximal heart rate during running} - \text{Heart rate after running}}{\text{Maximal heart rate during running} - \text{Heart rate at rest}}$$

○ Nakao (Japanese marathon runner),
△ Yokomizo (Japanese distance runner),
× Uchikawa (Japanese marathon runner),
※ Abebe (Ethiopian marathon runner),
◉ Kantorek (Czechoslovak marathon runner)

Fig. 21. A part of wireless telemeter attached to a subject. (Coutesy, Dr. Hideji Matsui)

220m/min. three times a week during 4 weeks, the following physiological changes were found besides the doubled increase of running time to exhaustion as compared with the test run. The subjects showed more rapid recovery of the heart rate after the test run on the treadmill and also an increase of the amount of oxygen uptake per one liter of ventilation volume at the last minute during 5 minute test running.

World famous champion runners, including Mr. Abebe Bikila of Ethiopia, Mr. Pavel Kantorek of Czechoslovakia, Mr. Oksanen of Finland and Mr. Julian of New Zealand, and Japanese top bracket distance runners as well as Japanese swimmers, visited the Physiologic Research Laboratory of University of Tokyo, and kindly collaborated to this research on endurance. They had contributed to the knowledge about the highest level of physical fitness respecting the endurance. They had the test of 5 minute running on the treadmill of 8.6% slope and the speed of 240m/min. after 3 minutes rest of a preliminary 2 minutes running at speed of 180m/min. According to the records of electrocardiograms during and after the test running, it was found that the recovery time of the heart rate after the 5 minute running should be one of the best indices of endurance, while the pattern of increase of the heart rate during running involved more complicated factors of fitness. It may be note worthy that every excellent distance runners sweated sufficiently over the body about 3 minutes after the start of running. This phenomenon could be the second wind. Without special training, one could hardly continue his running over 3 minutes on the treadmill at the same condition. This point should be the dead point for the untrained. Among these distance runners, there existed some differences of the amount of oxygen uptake per one liter of lung ventilation volume at the last minute during 5 minute test running. In one excellent runner, the oxygen uptake was 53cc. per 1 liter of ventilation. while in another less excellent runner 41cc. An the breaking point of all out running to exhaustion on the treadmill, however, the oxygen uptake per 1 liter of ventilation dropped to 30 ~35cc in all the subjects without regards to the running time. This might suggest a decrease of efficiency of absorption of oxygen into the circulation blood from the alveolar air must be due to shallow breathing at this stage of running and failure of a sufficient supply of the blood in the lung capillaries from the heart.

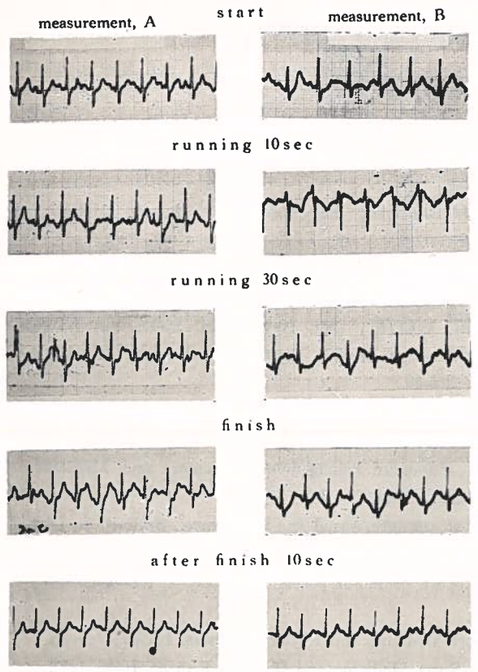


Fig. 22. Records of electrocordiograms from the chest of the subject before, during and after running with wireless telemeter. (Coutesy, Dr. H. Matsui)

It is of interest to know that researches on the same line has been conducted by W. Hollmann (6) of Germany suggesting a limiting factor of endurance may be a considerable increase of lung ventilation at the breaking point with the ergometer.

For measuring the heart rate during actual running, swimming, and other sports, telemetering apparatus has been working in the field of research in physical education and sports in this country these several years. In Fig. 21, the telemeter was shown attached to the runner. In Fig. 22, one of the records of electrocardiograms from the chest during running was presented by H. Matsui of University of Nagoya.

On the other hand, physical fitness should also be studied from the viewpoint of nutrition. Respecting the protein intake, physical performance has been studied extensively by S. Yamaoka of Kyoto Gakugei University.

The results of these researches will be reported in detail by the respective authors in future issues of this publication.

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PHYSIOLOGICAL STUDIES
OF
"CHOKING" IN JUDO

Physiological Studies of "Choking" in Judo

Society for Scientific Research of Judo,
Kodokan, Tokyo

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Y. Matsumoto (Kodokan),

Foreword

In order to study the effect upon the human body of "choking" in judo, the "Research Group for the Study of Choking in Judo" was formed within the Society for Scientific Research of Judo, Kodokan. "Choking" is a special technique used in judo, and it consists in strangling the neck of the adversary, thereby imparting pain or even making the oponent fall unconscious. Hence, the physiological studies on the effect of "choking" and its resulting unconsciousness is a matter of great import in order to obtain a proper understanding of judo, and also in the preventive aspect of the dangers accompanying judo.

The late Dr. K. Saito and his colleagues have made electroencephalographic studies during "choking", and have reported that the changes observed while the subject was in a state of unconsciousness resulting from the "choking", was identical to those observed in a patient during an epileptic seizure. In the present paper we wish to report our further studies on the subject.

The following were the main objectives of our studies:

1) The differences in the effect of the various methods of "choking".
2) The duration of the effect of "choking" on the body.
3) The physiological mechanism of the resulting state of unconsciousness.
4) The prevention of the dangers accompanying "choking".

I Experimental Procedure

Our experimental subjects were the following: Mr. Matsumoto, a sixth ranking judo expert performed the "choking" on four subjects of third ranking, and one sub ject of fourth ranking. On the same subjects three methods of "choking", the "Okurieri-jime", "Katajuji-jime", and "Hadaka-jime" were performed. In the "Okurieri-jime", the neck as a whole is squeezed, in the "Katajuji-jime" the region of the carotid arteries is pressed, while in the "Hadaka-jime", the trachea is pressed.

The subjects were made to lie on a bed in a recumbent position in a condition of rest, and in the case of the "Katajuji-jime", the performer did the strangling from the front. In the "Okurieri-jime", and the "Hadaka-jime", the upper part of the body of the subjects was raised approximately thirty degrees and the performer did the "choking" from behind.

Studies were made on the central nervous system, the cardio-vascular system, and the respiratory system.

The following items were selected.

1) Electroencephalogram (E. E. G.)
2) Percentage oxygen saturation of blood in the helix of the ear.
3) Electrocardiogram (E. C. G.)
4) Arterial blood pressure.
5) Finger and forearm plethysmogram.
6) Skin temperature.
7) Respiratory movement.
8) Pupillary reflex.
9) Reaction of urine
10) Cramp or convulsion.

At the first signal, the performer took the necessary position, at the second he performed the "choking", and let go his hold at the first sign of unconsciousness. The criteria for unconsciousness was the reflex dilatation of the pupils. Measurements were made at rest condition, then at the ready condition, and finally throughout the "choking" period until five minutes after awakening. Subsequent measurements were made at 10, 15, 20, 25, 30 minutes. The room temperature at the time of measurement was 15.6—18.2°C (dry temperature), and 12.0—15.4°C (wet temperature). The atmospheric pressure was 755.0—771.3 mm Hg.

II Experimental Methods and Results

1) General symptoms. The subjects fell unconscious after approximately 10 seconds of "choking". The duration of unconsciousness was from 10 to 12 seconds

and during this period, very often, the subjects developed clonic cramps. All subjects woke up spontaneously. While unconscious, the subjects sometimes had dreams which were not unpleasant. After awakening the subjects did not complain of any unpleasant feelings. The dilatation of the pupils was concomitant with the unconsciousness.

2) Electroencephalogram (E. E. G.). The subjects were put into an electrical shielding room, and with a unipolar lead, recordings were made from the frontal and occipital region. The silver disc electrodes were 1.0 cm in diameter, and these were applied to the frontal region, occipital region, and the ear lobe. An ink recording apparatus was used, and the recording paper made to move at the rate of 3 cm per second. None of the subjects fell unconscious during the "Hadaka-jime", but with the "Okurieri-jime", and the "Katajuji-jime" all subjects lost consciousness. In all the cases in which the subjects fell unconscious the E. E. G. were similar regardless of the method of "choking". (see Fig. 1)

a) In the getting ready position, the α waves were inhibited, and the β waves increased as compared to those in the rest position. This is due to the feeling of anxiety in anticipation of the "choking".

b) In the early stages of the "choking", the amplitude and the frequency were increased, followed by a decrease in amplitude.

c) Just at the time the subjects fell into unconsciousness, the amplitude markedly increased, and reached approximately 100 μV, while the frequency decreased conspicuously attaining 3-5 per second, and recorded the so-called slow waves. This we consider to be the characteristic E. E. G. of the state of unconsciousness following "choking", and is very similar to the E. E. G. of epileptic seizure. During the middle period of the state of unconsciousness, superposed waves appeared, followed by a separation, and finally became 50-100 μV, 3-10 per second waves.

d) As the subjects neared the awakening period, the δ waves identical to those which appear during sleep were observed, and these were superposed by β waves.

e) On awakening, the β waves became conspicuous, and after 10 seconds of awakening the α waves began to appear in addition. After 20 seconds of awakening, the E. E. G. showed a similar recording to that of the getting ready period. After 2-3 minutes the E. E. G. returned to that of the rest period.

In the case of the "Hadaka-jime", the E. E. G. showed an entirely different picture. Waves with wider amplitudes and higher frequencies appeared, but showed no slow waves. (see Fig. 1)

From the above six cases it is definte that changes in E. E. G. may be observed during the state of unconsciousness induced by "choking", but the duration is short, and 20 seconds after awakening the E. E. G. returns to normal and leaves no after effect, which is quite different from that of the case with a concussion

of the brain. In all the above cases the performer let go his hold immediately after the subjects fell unconscious, thereby limiting the effect of "choking" to a short period, but if the choking had continued longer, the appearance of serious after effect is to be expected.

3) Percentage oxygen saturation of blood in the helix of the ear. The apparatus used was the ear-oxymeter. This instrument measures the percentage oxygen saturation of the circulating blood in the helix continuously without puncture. With the ear-piece attached to the helix, measurements were made after the capillaries had dilated and became arterialized. The percentage oxygen saturation of blood at rest condition was fixed at 95%. The measurements were taken at parallel intervals with the E. E. G.. These measurements were made in order to investigate indirectly, the percentage oxygen saturation of the circulating blood in the brain, as the internal carotid artery which perfuses the brain, and the external carotid artery which perfuses the helix of the ear branch from the common carotid artery.

The changes in percentage oxygen saturation of blood in the helix during the "Okurieri-jime" and the Katajuji-jime", were similar to each other. The percentage lowered simultaneously with the commencement of the "choking", and the subject lost consciousness when the percentage dropped to 86%, and continued to fall for from 2 to 4 seconds, and reached a minimum of 82%. As the performer let go immediately after the subjects lost consciousness, the percentage rose quickly, and when it reached 90—92%, the subjects usually came to. Approximately 20 seconds after reviving consciousness the precentage regained the resting condition value. (see Fig. 2)

In the case of the "Hadaka-jime", as was stated, the subjects did not lose consciousness, and the fall in percentage oxygen saturation was far less marked than in the other two methods. (see Fig. 2)

From the above results it was observed that the percentage oxygen saturation of the blood in the helix of the ear decreased as a result of "choking" and the subjects lost consciousness when it fell markedly. It may be concluded that the oxygen lack of the circulating blood in the brain is one of the factors causing unconsciousness, as a result of "choking". But the fall in the percentage oxygen saturation is not low enough to attribute it as a sole factor in the cause of the uncosciousness.

4) Respiratory movement. In order to record the respiratory movement, a manchette was wrapped around the thorax, the changes in air pressure therein was transmitted to a recording tambour, and from thence recorded on a kymograph.

In the case of the "Okurieri-jime", and the "Katajuji-jime", the respiratory movement was inhibited in the inspiratory phase, with the commencement of the "choking". While unconscious the respiratory movement tended toward the expiratory

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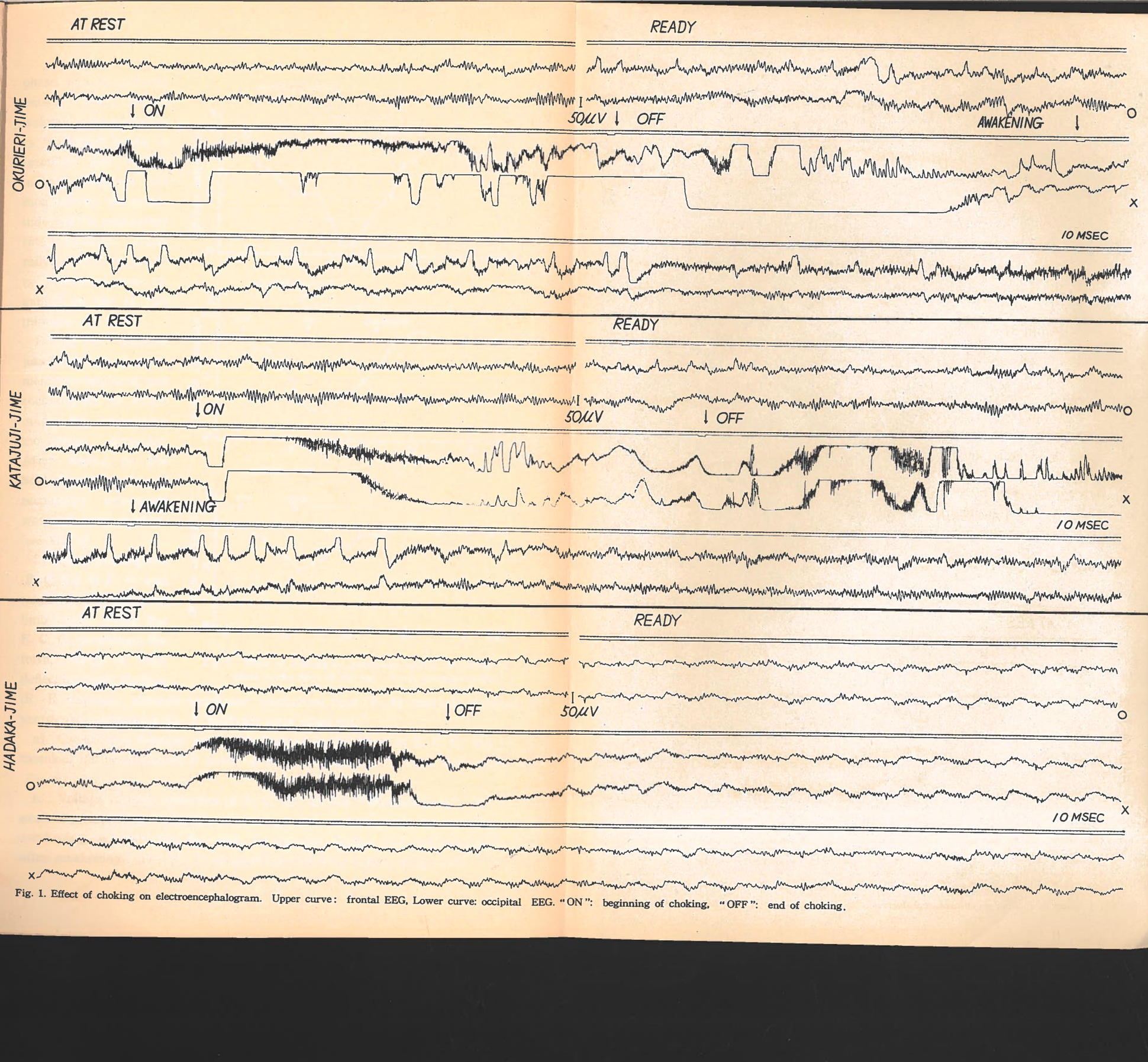


Fig. 1. Effect of choking on electroencephalogram. Upper curve: frontal EEG, Lower curve: occipital EEG. "ON": beginning of choking, "OFF": end of choking.

phase, and temporarily ceased. With the awakening, the respiratory movement began to resemble that of the normal condition, but momentarily, the amplitude and the respiratory rate increased. Generally, normal respiratory movement was regained in one to two minutes.

During the "Hadaka-jime", respiratory movement was inhibited, and coughing set in which made the respiratory movement irregular. After letting go the hold, the acceleration of respiratory movement was not very marked. (see Fig. 3)

5) Electrocardiogram (E. C. C.). E. C. G. was taken by the standard limb leads. From the E. C. G. recordings, the form, voltage of each deflection, heart rhythm (R—R interval), auriculo-ventricular conduction time (P—Q interval), duration of ventricular contraction (Q—T interval) were observed.

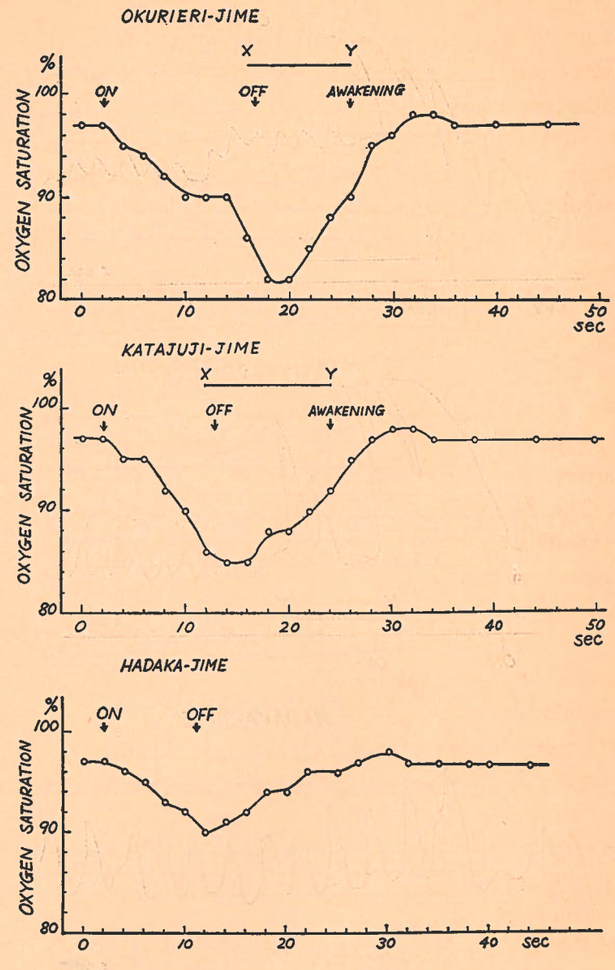
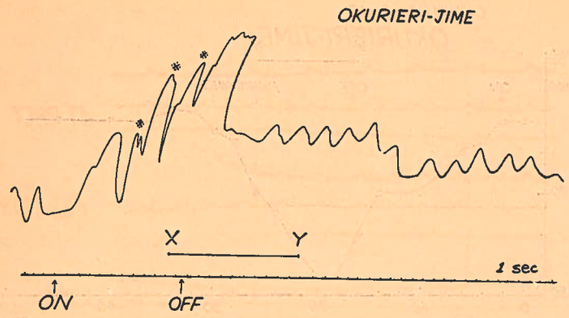
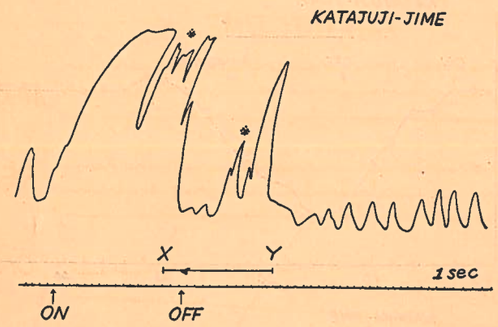


Fig. 2. Effect of choking on percentage oxygen saturation of the blood in the helix of the ear. X—Y, unconsciousness.

a) Conspicuous changes were not observed in the form of E. C. G., but an occassional disappearance of P wave, or the appearance of U wave were noted. (see Fig. 4)

b) Voltage of each deflection of E. C. G.. In the "Okurieri-jime", the R_I, T_I gradually became low from the beginning, and remained low for sometime after awakening, whereas the R_{III} and T_{III} became higher and remained high until after awakening. The R_{II}, T_{II} showed the following values, respectively: $R_{II}=R_I$





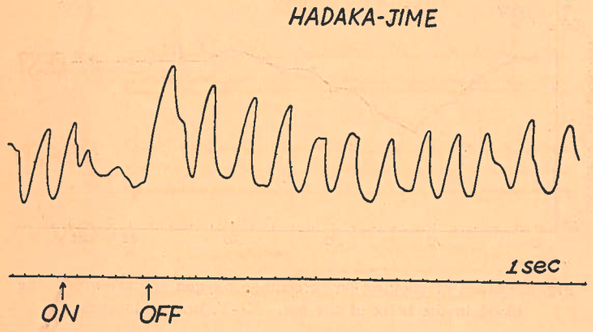


Fig. 3. Effect of choking on the respiratory movement.
Upward stroke of the record represents inspiratory movement.
At※, cramp was occured; during X—Y, unconsciousness.

$+R_{III}$. $T_{II}=T_I+T_{III}$ and generally maintained similar values, but during the unconscious period, the R_I, R_{II} and R_{III} occassionally showed higher values.

The above changes in voltage is, no doubt, attributable to the change in the electrical axis of the heart, but further thought must be given also to the change in cardiac output as a causal factor.

In the "Katajuji-jime", and the "Hadaka-jime", the R_{II} and R_{III} sometimes showed a high value during "choking", but in general, no regulal changes were observed. (see Fig. 5)

c) Interval of each deflection of E. C. G.. The R—R interval shows the heart rhythm. In all the methods of "choking", during the getting ready period, the R—R interval shortened. In the "Okurieri-jime", while the subject was unconscious, the R—R interval lengthened considerably, but with the awakeing, it shortened, and later lengthened again before going back to the rest condition, five minutes after regaining consciousness. (see Fig. 6) Meanwhile, practically no changes in the P—Q interval, and the Q—T interval, were observed. Accordingly, the changes in heart rhythm observed were mostly during diastole.

In the "Katajuji-jime", the changes were very similar to the foregoing, but the

changes in the R—R interval were not so pronounced. In the "Hadaka-jime", no changes in the R-R interval were observed (see Fig. 6)

These changes in E. C. G.,we assume, are the result of vagal inhibition on cardiac rhythm.

6) Arterial blood pressure. By means of the Tycos's sphygmomanometer, the blood pressure in the brachial artery was measured by the auscultatory method. During the "choking" act, it was rather difficult to measure due to the cramps, but after awakening, the systolic blood pressure rose 30—40 mm Hg, and within five minutes returned at the rest condition value. The diastolic blood pressure showed similar changes. (see Fig. 7)

7) Reaction of peripheral blood vessel. The volume change of finger and forearm was measured by plethysmograph. During the "Okurieri-jime", and the "Katajuji-jime", the volume of the fingers decreased, whereas that of the forearm increased. During the "Hadaka-jime", in which the trachea is mostly pressed, no such changes were observed. The changes observed during the "Okurieri-jime", and the "Katajuji-jime", were similar to the vaso-vagal syndrome. (see Fig. 8)

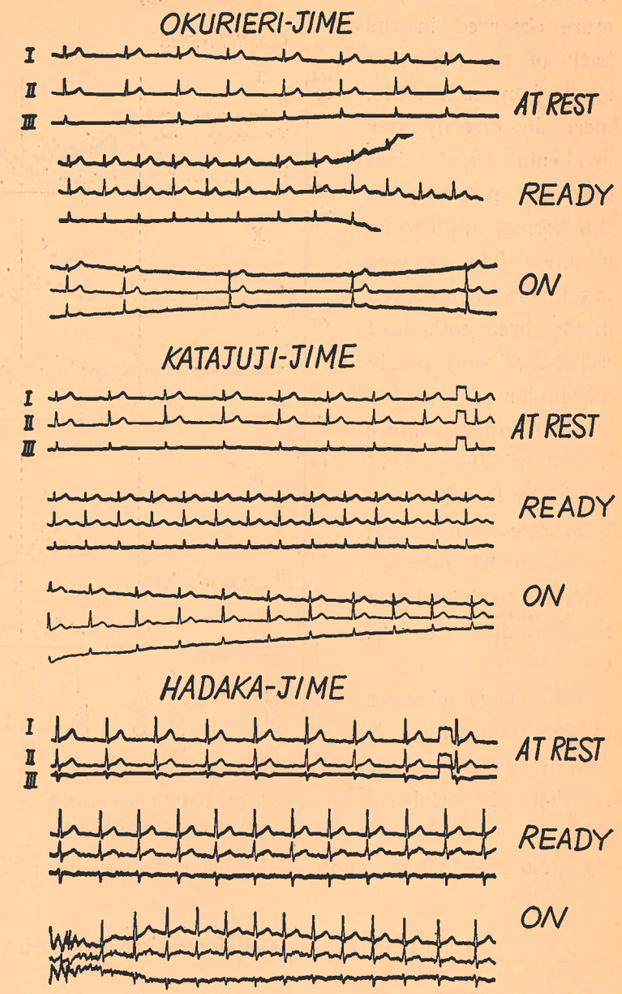


Fig. 4. Effect of choking on the pattern of electrocardiogram.

8) Skin temperature. A micro-pyrometer was used, and skin tempertures in the back of the leg of both sides, and the middle part of the lower lip were

measured. The temperature observed in the back of the leg were similar on both sides, increasing directly after awakening and then gradually returning to the normal in 25 to 30 minutes. The changes in temperature observed in the three mothods of "choking" were nearly all similar.

The skin temperature in the middle part of the lower lip fell directly after awakening, and in 20 to 30 minutes, returned to the value at rest condition. (see Fig. 9)

The above changes in skin temperature is considered a part of the reaction of peripheral blood vessel.

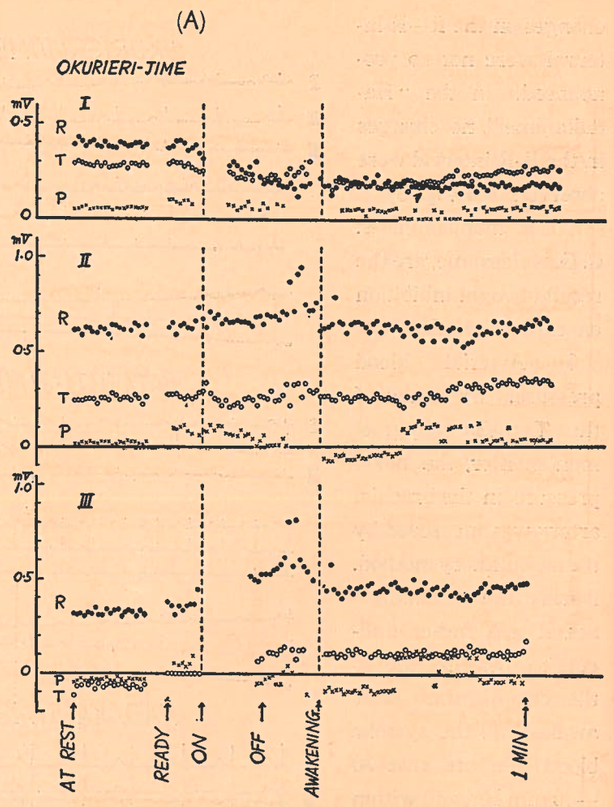


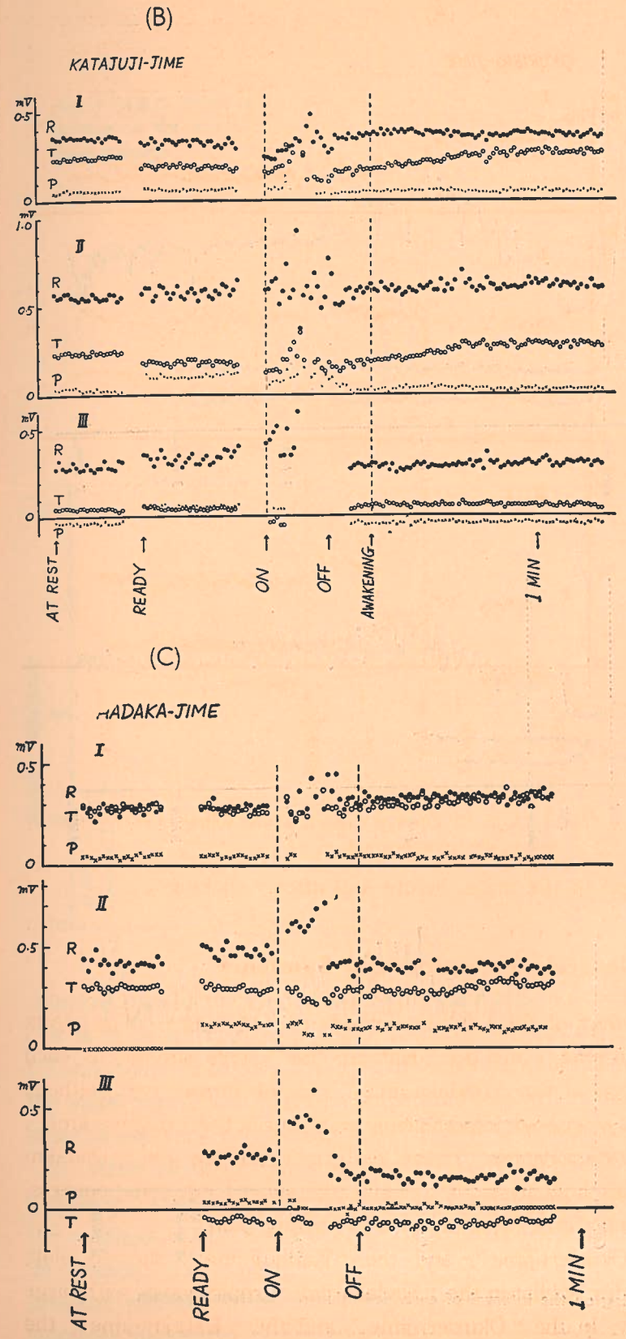
Fig. 5. (A. B. C) Effect of choking on the voltage of each deflection of electrocardiogram.

9) No protein was found in the urine, before and after "choking".

III General Discussion and Summary

1) The differences in effect of the various methods of "choking". The effects observed for the "Okurieri-jime", and the "Katajuji-jime" were similar to each other, but differed from that of the "Hadaka-jime". In the former two methods the subjects fell unconscious without experiencing pain, but in the "Hadaka-jime", the subjects did not lose consciousness. If the performer, during the "Hadaka-jime", had strengthened his hold in order to make the subject lose consciousness, the latter undoubtedly would have experienced excruciating pain.

The E. E. C. in the "Okurieri-jime", and the "Katajuji-jime" showed slow waves with large amplitudes, whilst in the "Hadaka-jime" rapid waves with large amplitudes were observed. In the "Okurieri-jime", and the "Katajuji-jime" the



percentage oxygen saturation of blood in the ear helix decreased to 82—85%, as a result of the "choking," but in the "Hadaka-jime", it barely reached 92%. It is inferred from the above results, that one of the causes of falling unconscious as a result of "choking" is oxygen lack of the brain.

The respiratory movement in the "Okurieri-jime", and the "Katajuji-jime", was inhibited in the inspiratory phase, whereas in "Hadaka-jime", it was inhibited in the intermediate phase. The E. C. G. showed the most marked elongation of the R-R interval in the "Okurieri-jime", then in the "Katajuji-jime", but in the "Hadaka-jime" it was very slight. The reaction of the peripheral blood vessels in the "Okurieri-jime", was manifested by a marked constriction of blood vessels of the fingers and also a slight dilatation of blood vessels of the forearm. The "Katajuji-jime" produced similar change, although not so

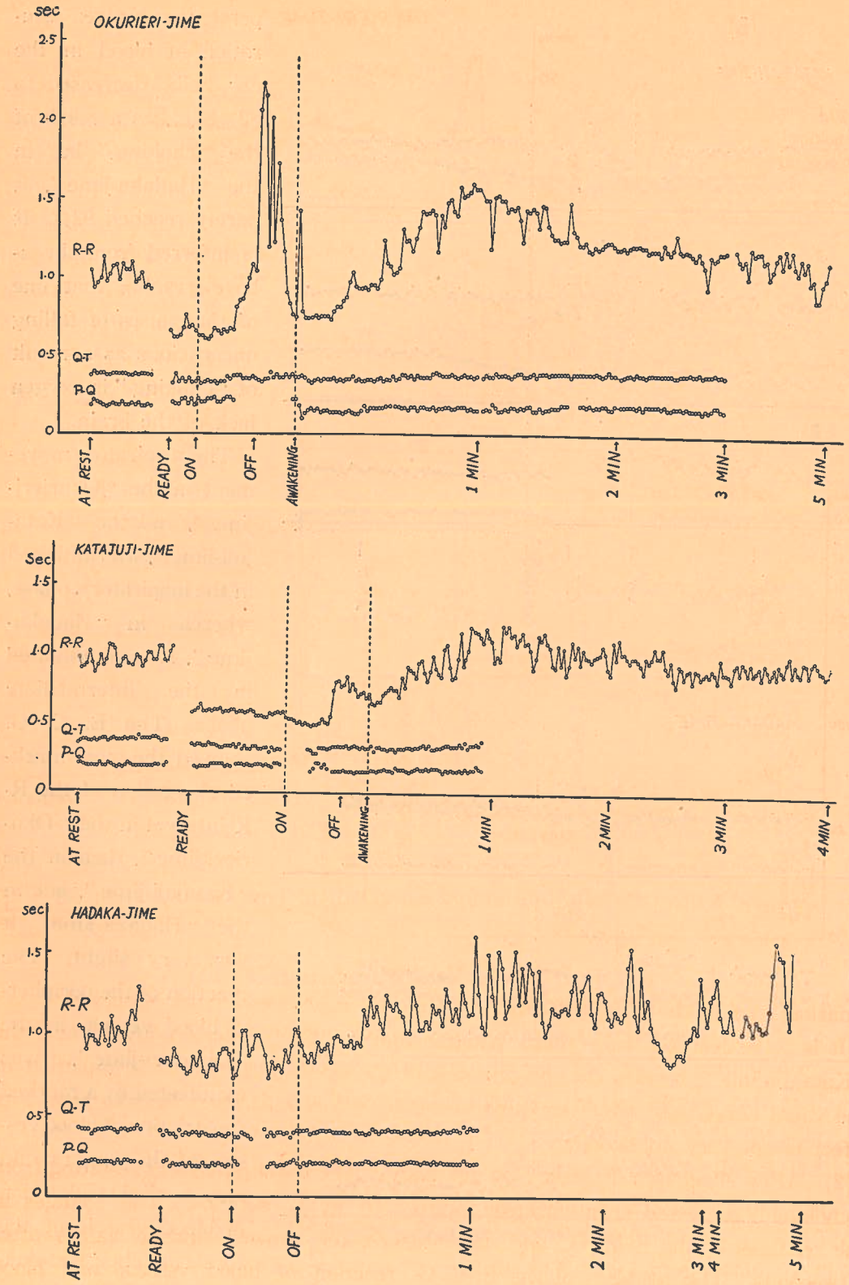
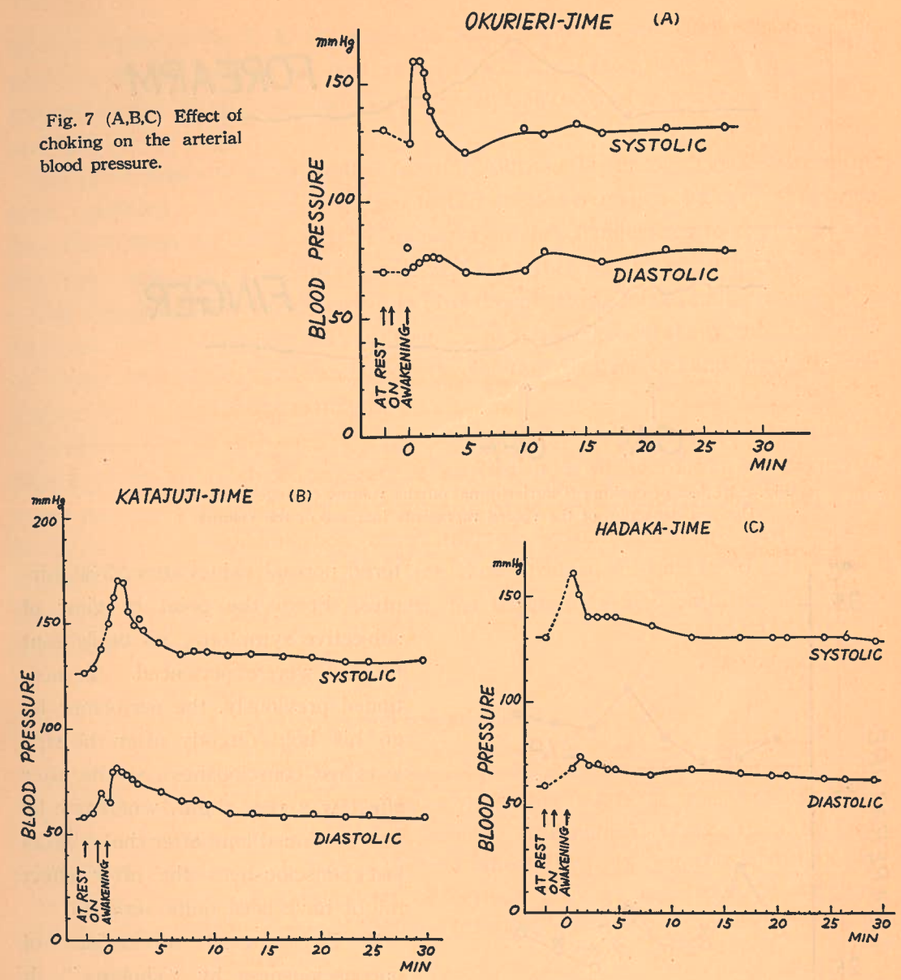


Fig. 6. Effect of choking on the interval of each deflection of electrocardiogram.

Fig. 7 (A,B,C) Effect of choking on the arterial blood pressure.



marked, but in the "Hadaka-jime", practically no changes were observed.

It is to be learned from these results, that in the "Okurieri-jime", and the "Katajuji-jime", besides the oxygen lack of the brain, the effect of stimulation of the vagal nerve, also plays an important role, whereas in the "Hadaka-jime", its effect is not very noteworthy.

2) After effect of "choking" on the body. The unconsciousness resulting from "choking" recovered spontaneously in from 10 to 12 seconds. The changes in the readings of the E. E. G., and the ear-oxymeter, showed normal values after 20 seconds. The readings of the E. C. G., reaction of blood vessels, and blood pressure returned to normal values after 5 to 10 minutes. The changes in respiratory movement recovered after 5 minutes. Skin temperature readings regis-

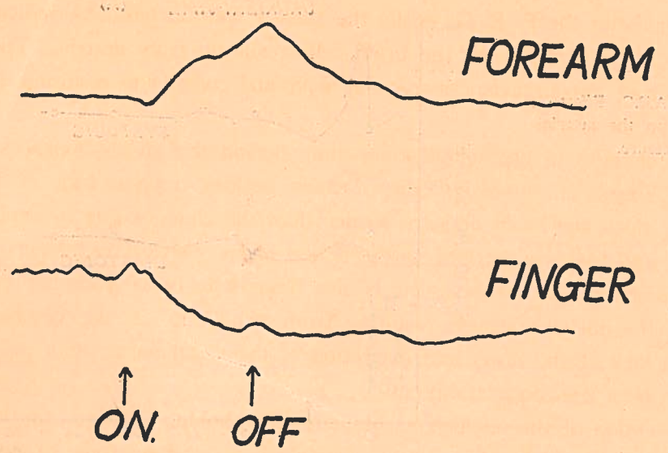


Fig. 8. Effect of choking (Okurieri-jime) on the volume of finger and forearm. Upward deflection of the record represents increase of the volume.

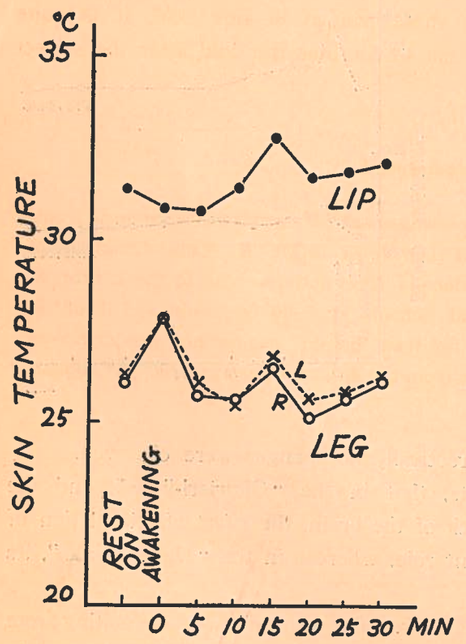


Fig. 9. Effect of choking on the skin temperature. No marked difference in the effect on the skin temperature was obtained by three methods of choking. The skin temperature plotted in the figure is the mean of all the subjects. R: right leg, L: left leg.

tered normal values after 25-30 minutes. From the point of view of subjective symptoms, no unpleasant feelings were experienced. As mentioned previously, the performer let go his hold directly after the subjects lost consciousness, so the after effect was very slight, whereas if he had continued long after the subjects lost consciousness the after effect might have been quite serious.

3) Physiological mechanism of unconsciousness by "choking". It is clear from the fact that in the "Hadaka-jime", wherein pressure is applied mostly on the trachea, the subjects did not fall unconscious, and also from the readings of the ear-oxymeter, the cause of the unconsciousness resulting from the other two holds may be attributed to oxygen lack of the brain as a result of mechanical hindrance of the blood stream to the brain. The appearance

of slow waves in the E. E. G., while the subject was unconscious, indicates a depression of the activity of the brain cells resulting from anoxia. The onset of cramps during unconsciousness may be asphyxial convulsion resulting from oxygen lack of the brain.

But the changes in physiological function, during the unconsciousness resulting from "choking", is caused by other factors besides oxygen lack of the brain. The effect upon the heart appears sooner than the changes due to oxygen lack of the brain, and may be ascribed to the action of the cervical vagal nerve.

The reaction of the blood vessels is also thought to be of a similar cause. Accordingly, the unconsciousness resulting from "choking" is the combined result of oxygen lack of the brain and excitation of the vagal nerve, and may be considered to be a pre-shock symptom.

4) Prevention of the dangers accompanying "choking". Since the load for the heart and the rise of blood pressure is marked, it is dangerous to perform the "choking" hold on subjects with heart trouble or with hypertension. It is also dangerous for youngsters whose central nervous system and heart have not yet attained complete development. But for those trained in this field, it is quite harmless, although care must be taken, not to continue the hold after the subject falls unconscious.

Acknowledgement

The authors wish to express their acknowledgement for considerable aid and encouragement received throughout the course of their work to Mr. R. Kano, Chairman of Kodokan, and also to the members of Kodokan. The authors wish to thank Prof. K. Hukuda of University of Tokyo Medical School, Prof. R. Sugimoto and Prof. R. Natori of Tokyo Jikei-kai Medical School for their helpful suggestions and criticism. The expenses of this research was defrayed from the Research Fund granted by Kodokan.

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Some factors modifying the expression of human strength

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IKAI, MICHIO AND ARTHUR H STEINHAUS. *Some factors modifying the expression of human strength.* J. Appl. Physiol. 16(1): 157–163. 1961.—The maximal pull of forearm flexors was increased and, in some instances, decreased in predictable fashion by a loud noise, by the subject's own outcry, by certain pharmacologic agents (alcohol, adrenaline, and amphetamine), and by hypnosis. Significant average changes ranging from +26.5% to −31% were observed. An analysis of these data and that of others leads us to regard all performances short of the maximum limit, which is always imposed by the structure and prevailing physiologic state of the performing muscles, to be manifestations of acquired inhibitions that in turn are subject to disinhibition by pure Pavlovian procedures, by anesthetization of inhibitory mechanisms, or by pharmacologically induced symptoms serving as stimuli for disinhibition.

THE PULLING POWER of a muscle is ultimately a function of its cross section and the physiologic state of its tissues; but the actual performance of a muscle fluctuates more rapidly and over a wider range than can be fully accounted for by changes in these factors. In fact there are many reasons for assuming that the muscle and peripheral nerves are the most stable links in the neuromuscular sequence that produces a voluntary contraction. The causes of rapid and reversible changes in muscle strength must therefore be sought in central mechanisms.

Changes in the central nervous system may be brought on by factors that modify the physicochemical state of neurons and synapses such as oxygen tension, hormones, pharmacologic agents, and temperature changes. Collectively, these may be designated neurologic or physiologic factors. The activity of nerve centers and their influence on activity is further determined and modified by the racial history and individual experiences of the organism. Individual experiences account in large measure for differences in action between persons and for differences in the action of the same person from moment to moment and day to day. Although this behavior is always subject to physicochemical factors already mentioned, its individual character is primarily the result of environmentally induced experiences that include every impact with the inanimate and animate world, including experiences with parents, teachers, and peers. Although it is futile to attempt a clean dissection between the effects of such individual learning experiences and those of physicochemical origin on the expressions of strength, it is relatively easy to identify two categories of initiating agents that differ in their manner of working. Because the *modus operandi* of physicochemical agents has been most closely observed by physiologists, they are designated 'physiologic' factors, and because the actions of man's animate environment and culture on his behavior have engaged the attention of persons interested in his psyche, those actions are designated 'psychologic' factors. Granted that both factors operate on the same nervous system and granted that psychology is a special phase of brain physiology, it is nevertheless useful to speak of physiologic and psychologic factors. Physiologic factors set the relatively fixed and outermost limits, psychologic factors, the more proximate ones. In this sense it is appropriate to speak of a physiologic and a psychologic limit. Capacity is the always undetermined measure of the former. Performance is always limited by the latter.

Factors that determine the physiologic limit are relatively well understood. The aim of this study is to throw light on the mechanism that determines the psychologic limit and how this limit is changed.

METHODS AND RESULTS

The tension of right forearm flexors in maximum effort was measured with a cable tensiometer as described by Clarke (1). A specially adapted armchair positioned the seated subject's forearm at right angles to his upper arm. A wide canvas belt fastened to the subject's wrist was attached to a 1/8-inch cable that descended perpendicularly and at right angles to the forearm to fasten into the same base to which the chair was fastened. Cable tension resulting from maximal efforts to flex the forearm was read in arbitrary units on the tensiometer dial and converted to pounds by reference to a calibration curve.

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TABLE 1. *Statistical Analysis of Changes in Human Forearm Flexor Strength Induced by Certain Psychologic and Pharmacologic Interventions*

Means Compared	N	M_1, lb.	M_2, lb.	$M_2 - M_1$, lb.	Change, %	σ	t	P	Significance
1. All pulls per session without shot 2. All pulls per session preceded by shot	35	61.5	66.0	+4.5	+7.4	0.82	5.48	0.001	Highly significant
1. All pulls per session without shot or shout 2. Pull with shout	35	61.5	69.0	+7.5	+12.2	0.95	7.89	0.001	Highly significant
1. Prehypnotic pulls 2. Pulls in hypnosis under suggestion of strength	6	69.2	87.5	+18.5	+26.5	6.88	6.50	0.01	Highly significant
1. Prehypnotic pulls 2. Posthypnotic pulls under suggestion of weakness	6	69.2	47.3	−21.9	−31.7	12.50	4.38	0.01	Highly significant
1. Prehypnotic pulls 2. Posthypnotic pulls under suggestion of strength	6	69.2	84.7	+15.5	+22.5	9.89	4.10	0.01	Highly significant
1. Prehypnotic pulls 2. Pulls in waking state after hypnosis	6	69.2	82.1	+12.9	+18.7	8.73	3.70	0.02	Significant
1. Pulls in blank control (adjusted) from 6th to 30th min. 2. Pulls from 2nd to 27th min. after alcohol	10	66.3	70.0	+3.7	+5.6	2.80	1.32	0.3	Not significant
1. Pulls in blank control (adjusted) from 6th to 30th min. 2. Pulls from 2nd to 27th min. after adrenaline	10	71.8	76.5	+4.7	+6.5	3.17	1.48	0.2	Not significant
1. Pulls in blank control (adjusted) from 6th to 30th min. 2. Pulls from 30th to 60th min. after 30 mg amphetamine sulphate	10	70.5	80.0	+9.5	+13.5	3.65	2.60	0.05	Significant

b) The average of single, terminal pulls accompanied by a shout compared with the mean of the averages of all pulls not immediately preceded by a shot or shout discloses a 7.5-lb. or 12.2% increase attributable to the shout. This improvement, also, is highly significant ($P = 0.001$).

c) Although we have insufficient data for statistical analysis we are satisfied that the time elapsed between the shot and a subsequent pull in some way influenced the effect of the shot on the pull. In preliminary test sessions, lower-than-normal pulls were so often recorded when the shot was fired simultaneously with the pull that we discontinued this practice and did not include sessions with this timing in the 35 sessions here reported.

d) Figure 3 shows how greatly subjects varied in their responses to the shot. Thus *subject PH* showed no response whatever, whereas others (*JR* and *PC*) showed increases of more than 30% following shots; several subjects (*TM* and *PC* on April 24) appeared to show a postponed effect of the shot, marked by increased performance in the second and third pulls after the shot; and the same subject might show very different responses on different days (compare *PC* on April 24 and May 10).

Hypnosis series. Each of the 10 subjects employed in the *blank control series* was subjected to hypnosis. Of this group three proved refractory in repeated attempts to hypnotize them. The procedure involved fixation of vision on the timing clock. This was followed by instructions to close the eyes and imagine the clock receding into the distance plus various other suggestions to induce relaxation and sleep. In from 10 to 15 minutes the subjects were tested for certainty of the hypnotic state by simple suggestions of rigidity and limpness of arms and legs. When the arm was held so rigid that neither the hypnotist nor his associate could bend it the subject was considered ready for further testing. He was then told that he could now see the clock, that he was getting stronger and stronger, that he could break all records, and that nothing would hurt while he did it. Then followed five measures of strength, which he performed in time with the sweep hand of the clock in 5 minutes. He was then told that at the count of three he would awaken but find himself very weak for 5 minutes, that his muscles would pain when he pulled against the strap, that at the end of five pulls he would become very strong for five successive pulls, and that on command he would thereafter return into a deep sleep. Upon the hypnotist's third count the subject awoke, waited until the second hand reached the one o'clock position as instructed, and pulled just as he had been told for 10 times. Invariably the first five pulls were considerably below his normal and the subsequent five pulls were very strong. The operator then told him

to go to sleep. In this second sleep he was given suggestions that when he awoke on subsequent command he would feel wonderful, better than he had felt for a long time, etc. He was then awakened and told the hypnosis test was all over but that he should pull another five times. Six of the seven subjects who were hypnotized showed identical response patterns. Their performances are reproduced in a composite curve in figure 4. Because of variations in the time taken to induce hypnosis in these subjects the time scale on the horizontal axis is not continuous. Suggestions of strength increased the average pull 18.3 lb. under hypnosis and 15.5 lb. in the state of posthypnotic suggestion (see table 1). Suggestions of weakness and pain reduced the average strength in a period of posthypnotic suggestion nearly 22 lb. below the prehypnotic controls. All these differences are highly significant ($P = 0.01$). In the terminal waking state there was persistence of the strength increase at a somewhat reduced level, i.e. 12.9 lb. above the control with a P value of 0.02 for the difference.

The seventh subject who responded to hypnosis deserves special presentation. This subject, whose record is given in figure 5, was an experienced weight lifter. Somewhat skeptical of hypnosis, he set out to disprove it. In consequence, he made an exceptional effort and pulled as much as 160 lb., breaking all previous records, in his prehypnosis pulls. After three attempts extending over nearly 2 hours he was finally hypnotized. His display of strength both in the hypnotic state and under posthypnotic suggestion never fully equaled his superefforts in the control period. Maximal effort under hypnosis in one instance caused him to pull himself down and nearly off the chair. This no doubt reduced his recorded performance. The posthypnotic suggestion of weakness was, however, very effective as in the other six cases. To satisfy ourselves and him that he really had been hypnotized

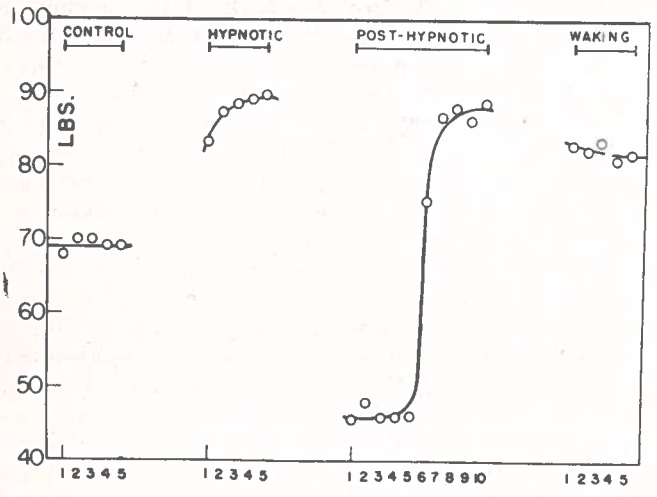


FIG. 4. Average performance of 6 subjects under hypnotic suggestions of strength and posthypnotic suggestions of weakness to be followed by strength, compared with prehypnotic control and posthypnotic waking states. Time on horizontal axis is discontinuous because of varying lengths of time devoted to inducing appropriate hypnotic states.

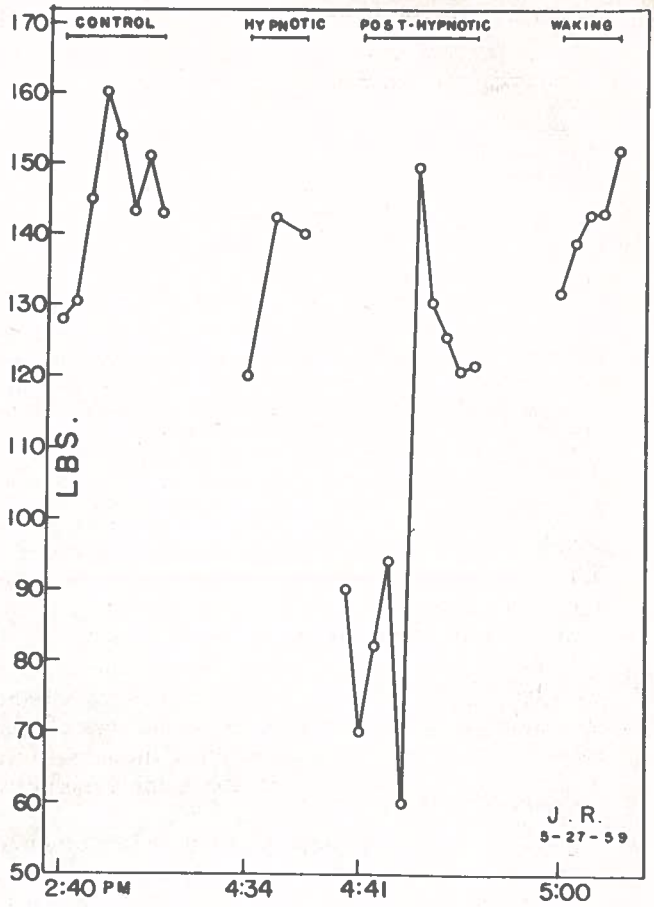


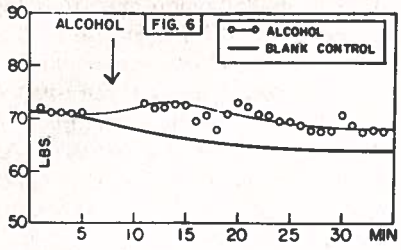
FIG. 5. Record of unusual forearm flexor performance in hypnotic series. *Subj. JR*, an expert weight lifter, set new record in control period which apparently approximated his physiologic limit and, therefore, was not exceeded under hypnotic suggestion.

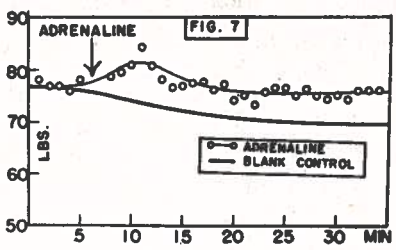
he was told that the hypnotist would brand his hand with a red-hot poker and that this would cause a blister to form. When he was touched with the hypnotist's closed fountain pen he screamed. The blister that appeared within the hour took a week to heal and served to convince the subject of the reality of hypnosis.

We interpret the findings in this subject to indicate that he was able, probably because of long training, to approximate his physiologic limit in the waking state and therefore suggestion could lower but not further raise his performance.

Alcohol series. The 10 subjects used in the *blank control series* were observed in five maximum pulls before the consumption of 15–20 ml of 95% ethyl alcohol in water. Two minutes after the alcohol was taken testing was continued once a minute for 25 minutes. Each circle in figure 6 represents the average of 10 pulls (one by each subject) recorded for the minute indicated. The curve of the blank control has been drawn on the graph in an adjusted position determined by overlapping the curve of the first five pulls of the control with the five prealcohol pulls of the experimental series.

In order to assure, for the statistical analyses presented





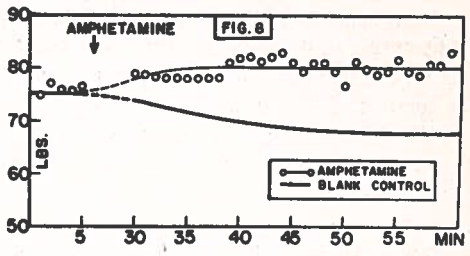


FIG. 6. Average of maximal forearm flexor performances of 10 subjects after consumption of 15 to 20 ml of 95% alcohol in water compared with average performances of the same subjects in *blank control series*. *Control curve* is adjusted vertically to level of prealcohol tests. *Arrow* indicates taking of alcohol.

FIG. 7. Average of maximal forearm flexor performance of 10 subjects after 0.5 ml of a 0.1% solution of adrenaline intramuscularly compared with average of same subjects in *blank control series*. *Control curve* is adjusted vertically to level of prealcohol tests. *Arrow* marks injection time.

FIG. 8. Average of maximal forearm flexor performance of 10 subjects before and after 30 mg amphetamine sulphate by mouth compared with average of same subjects in *blank control series*. *Control curve* is adjusted vertically to level of preamphetamine tests. *Arrow* marks taking of amphetamine.

in table 1, valid comparisons of our findings under the influence of alcohol, adrenaline, and amphetamine with a comparable set of control values the following was done: the difference between the average of the first five pulls in the *blank control series* and the average of the five pulls before administering the pharmacologic substance was added or subtracted from the blank control values of each minute depending on whether the initial values of the control were below or above the experimental values, respectively.

For each session all pulls recorded after alcohol consumption were averaged. The mean of the 10 averages after alcohol compared with the mean of the 10 averages of the adjusted blank control performances of the same 10 subjects disclosed an increase of 3.7 lb. attributable to alcohol. This improvement of 5.6%, although not statistically significant, is discussed further below.

Adrenaline series. The same 10 subjects were injected intramuscularly with 0.5 ml of a 0.1% solution of adrenaline after recording five maximal pulls. Two minutes later strength testing was resumed at intervals of 1 minute for 27 minutes. The average performance of the 10 subjects at each minute is graphed in figure 7 together with the curve of the blank controls for the same subjects, adjusted graphically as described for alcohol.

Statistical treatment of these data as for alcohol shows an improvement of 4.7 lb. (6.5%), which is not significant.

Amphetamine series. Each of the same 10 subjects was tested five times in 5 minutes before taking three 10-mg tablets of amphetamine sulphate by mouth. Twenty-five minutes after taking amphetamine, testing was resumed and continued at 1-minute intervals for 30 minutes. The average of the pulls of the 10 subjects at each minute is graphed in figure 8 together with the blank control curve adjusted as for alcohol and adrenaline.

A statistically significant improvement of 9.5 lb. (13.5%) attributable to the amphetamine effect is recorded in table 1.

DISCUSSION

All observations reported here support the thesis that the expression of human strength is generally limited by psychologically induced inhibitions.

The various interventions by which we increased performance in one way or another reduced these inhibitions. The greatest and most consistent extension of performance took place in hypnosis, a purely mental phenomenon. The early, apparently excitatory, effect of alcohol is properly attributed to its primary narcotic action on inhibitory mechanisms, but this is followed by more widespread depression. Figure 6, by conforming to this sequence of events (i.e. increased performance followed by reduction), thus also supports our basic thesis.

Increased performances under drugs, excitement states, and hypnosis have been reported also by others but few persons have proposed possible mechanisms for their explanation. Campos, Cannon, Lundin and Walker (2) in 1929 observed in dogs the lifting of muscular fatigue by injections of adrenaline but with far from uniform results. They believed the explanation should be sought in a central mechanism but confessed complete ignorance as to its nature. Ten years later Lehmann, Straub, and Szakáll (3) in exhaustive experiments established that Pervitin (1-phenyl-2-methylaminopropane) produced up to threefold increases of performance on a bicycle ergometer. Finding no metabolic changes or improved circulatory adjustments to account for the increases and always finding exhaustion signs commensurate with the work performed, they concluded that Pervitin in no way improved physiologic mechanisms but merely served as a central excitant. They said the end point of any performance is never an absolute fixed point but rather is when the sum of all negative factors such as fatigue and muscle pain are felt more strongly than the positive factors of motivation and will power. Pervitin, they added, lets the former appear weaker and the latter stronger, thereby extending the subjective limits of performance to use up more of the reserves that normally protect the individual from excessive exhaustion. Alles and Feigen in 1942 (4) reported greater performance in man under amphetamine. They said the drug inhibits the production of fatigue. Systemic circulatory effects following their higher doses of Benzedrene (20 and 40 mg) cannot, according to them, account for the improved performance by any direct effect on the muscle. They looked for limiting factors and for the Benzedrene effect to reside in the central synapses but

dared not speculate further. Of special interest is their finding that the amplitude of the patellar reflex increases under Benzedrene coincidentally with the Benzedrene prolongation of finger flexion recorded on a Mosso type of ergograph. Since exaggeration of the patellar reflex is itself a sign of release from higher central domination and also the first sign of oxygen deprivation of higher centers, it is not unreasonable to postulate a directly chemical or a pharmacologically triggered disinhibition to explain these findings. Spengler in 1957 (5) also identified amphetamine as prolonging performance through action on higher centers but suggested no possible mechanism for its action.

More recently amphetamine (1-phenyl-2-aminopropane) as amphetamine sulphate was employed in studies by Smith and Beecher (6) and by Karpovich (7) to determine the action of so-called 'pep pills' on performance in various swimming, running, and weight events. In addition to simple placebos, Smith and Beecher (6) used alternately also secobarbital, acclaimed to possess euphoric and depressing effects, to help isolate the real amphetamine effect. Both studies report great variations in performance attributable to the drug. Smith and Beecher (6) found improved performance in a majority (about 75%) of athletes under amphetamine. Some also did better under secobarbital than placebo and some did best on placebo. They found less amphetamine effect when performance was in competition against test mates than when it was singly timed. Excluding weight events, amphetamine performance never equaled performance in true competition except when a selected group of swimmers were specially motivated by the promise of a steak dinner, which at Harvard has become an award of great symbolic significance. Thus amphetamine substituted in part for the excitement of competition. Karpovich (7), on the other hand, found no significant difference in 50 of his 54 subjects. Only three swimmers did better on amphetamine and one did significantly better on placebo.

Both studies express concern over the inability to separate drug and psychologic causes. Smith and Beecher say, ". . . it was possible for the performance to be better on 'amphetamine days' than on 'placebo days' not because the 'pep pills' invigorated the athlete or heightened his motivation but simply because he noticed unusual feelings and sensations and assumed this meant he had been given the 'pep pill', expected help from it, and so performed better than usual." It is significant that both the depressant secobarbital and the excitant amphetamine are reputed to have euphoric effects. If the small doses of secobarbital associated with a fair number of improved performances were sufficient to elicit the euphoria without significant depression, then such improvement may also have been due to the triggering of a psychologic mechanism by a drug-induced symptom. Since all of our subjects reported marked symptoms resulting from these drugs, this interpretation seems best to explain our own findings with amphetamine sulphate, epinephrine, and perhaps alcohol. From experiences of everyday life as well as from Pavlovian experimentation (8) there is ample evidence that any unusual sensory experience or excitement may inhibit inhibitions. Such disinhibition may well account for all improvements noted in these experiments and for the even greater performances exhibited in bona fide competition. Alternately, the secobarbital effect may be explained as pharmacologic suppression of inhibitions as postulated above for alcohol.

In the *shot and shout series* our procedure most closely follows that of Pavlov. In fact this study was conceived in our laboratory nearly 5 years ago when we sought to parallel on man Pavlov's experiments with external inhibition. If one assumes that the expression of strength is normally restrained by the aches of sprains and strains associated with maximal effort, even by the sharp admonitions of overprotective parents against overdoing, and that these operate as conditioned stimuli of inhibiting or negative conditioned reactions, then such inhibitions, as in Pavlov's dogs, should be subject to external inhibition by loud sounds, etc.

In our experiments the sweep hand coming to the one o'clock position served as the stimulus for a conditioned response, the contraction. A surprise shot fired simultaneously with this stimulus would be evoking the 'orienting or focusing reflex', or by otherwise acting as an external inhibitory agent, inhibit the contraction response and thus account for the lesser strength usually noted with such synchronism. Accepting the view that such inhibition radiates over the cortex to involve many neural centers, the greater-than-normal pulls exerted when the shot preceded the pull by 4 to 10 seconds would be explained by the inhibition of inhibiting mechanisms in areas to which the shot-induced inhibition had, in the intervening time, spread. Should such spreading continue for as much as 90 seconds, as claimed by Bykov (9) from the findings of Krasnogorsky, Fursikov and Kogan, we could account in this way also for the instances in which we found above-normal strength in the second pull, as long as 64 seconds after the shot.

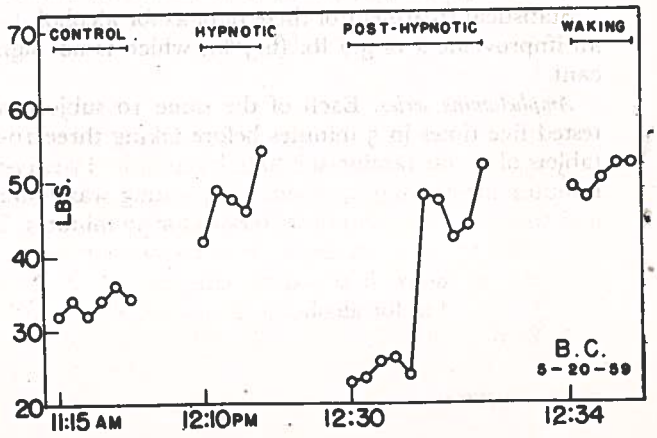


FIG. 9. Case of a young woman displaying unusual improvement of strength under hypnosis. This case provided clues to probable cause of normally prevailing inhibitions.

Les Japonais, la science et la technologie

par Marc Dupuis

Marc Dupuis, polytechnicien, est actuellement professeur de chimie physique théorique à l'université Paris VI. Il doit sa connaissance de la science et de la technique japonaises à un premier séjour de trois ans comme chercheur à l'université de Tokyo, puis à un deuxième de près de dix ans comme conseiller scientifique près l'ambassade de France. Conseiller du ministère de l'Industrie, il est amené à retourner très fréquemment au Japon.

■ Le temps n'est pas si éloigné où l'image scientifique du Japon en France était encore essentiellement celle d'un pays qui ne savait qu'imiter. De cet extrême, il semble que l'on soit maintenant tombé dans un autre : certains veulent voir dans le Japon le pays le plus futuriste du monde et en brossent un tableau où l'on ne voit plus que robots, microprocesseurs et biotechnologie.

■ Ce qui est certain, c'est que le Japon s'est hissé au premier plan dans les technologies de production de masse. Ce qui est reconnu aussi, c'est que non seulement au niveau des technologies de production mais également à celui des produits, le Japon ouvre maintenant la voie dans certains domaines, y partageant la première place avec d'autres. Ainsi est-il généralement admis par les spécialistes, qu'à la suite de l'achèvement du plan de développement des circuits intégrés à très haut degré d'intégration (VLSI) lancé en 1976, le Japon est maintenant en tête, à égalité avec les États-Unis, dans ce secteur d'extrême pointe.

■ Sans entrer ici dans une revue systématique et fastidieuse des principaux domaines technologiques, on peut dire que le Japon a une position forte dans des secteurs aussi divers que la sidérurgie, la mécanique de précision, la robotique, les communications optiques, la biotechnologie, l'aquaculture, la construction antisismique et les transports terrestres à haute vitesse. Cette seule liste, qui n'a nullement la prétention d'être exhaustive, témoigne d'un haut niveau de la technologie japonaise dans de larges zones, même si subsistent aussi certaines zones de faiblesses telles que la prospection pétrolière sous-marine et l'aéronautique ou si coexistent des points de faiblesse et des points forts dans certains domaines importants : par exemple l'avance dans les VLSI n'empêche pas qu'il existe un retard dans les circuits intégrés spéciaux à usage militaire.

■ Dans ces conditions une question subsiste, que le lecteur s'est sans doute déjà posée : même si le Japon peut être maintenant considéré comme un pays dont la technologie compte, est-il pour autant un pays dont la science compte ?

■ Ce qui caractérise l'avalanche des articles publiés en France depuis un an ou deux sur le Japon est l'absence de recul historique. Ce pays est souvent étudié comme si son histoire avait débuté récemment ou après la Seconde Guerre mondiale. Or, beaucoup de spécificités du Japon actuel s'expliquent naturellement ou ne prennent leur véritable signification que sous un éclairage historique.

La science japonaise a été initialement, comme l'on peut s'y attendre, la science importée de Chine. Bien que certaines connaissances et certaines techniques aient vraisemblablement déjà été importées individuellement par les immigrants des quatrième et cinquième siècles, la trace la plus ancienne d'une initiative officielle remonte à l'année 533, où l'empereur du Japon demanda à la cour de Paekche, en Corée, de lui envoyer des spécialistes en science du calendrier, en divination et en médecine. Cet envoi fut suivi d'autres et, à partir du VII[e] siècle, le Japon organisa lui-même des missions d'études en Chine, jusqu'à l'an 894 où elles furent arrêtées par décret impérial. A cette première vague d'influence chinoise, succédèrent quelque cinq cents années durant lesquelles les contacts entre les deux pays furent très réduits. Avec la reprise de relations commerciales officielles au début du XV[e] siècle, la science chinoise connut un regain d'intérêt au Japon grâce aux nouveaux apports qui accompagnèrent cette reprise, avant de céder définitivement la place au milieu du XIX[e] siècle à la science occidentale avec laquelle le Japon avait eu son premier contact en 1543, lorsqu'un bateau à bord duquel se trouvaient des Portugais portant des armes à feu s'échoua sur l'île de Tanegashima, au sud du Japon.

Durant cette longue période d'influence chinoise apparaissent déjà certaines spécificités de la démarche japonaise, qui permirent au Japon de négocier cette rencontre avec la science occidentale sans difficulté, à l'inverse de la Chine. Ces spécificités s'observent au mieux dans l'astronomie qui, à cette époque, occupait une place centrale dans l'activité scientifique. Comme le fait observer l'historien Nakayama Shigeru,[1]* l'astronomie chinoise était une science exacte qui recherchait des régularités. Au contraire, pour les astronomes japonais, l'objectif n'était pas de rechercher des régularités dans la nature, mais de prédire ce qui allait se passer et de pouvoir prendre les mesures éventuellement nécessaires : une éclipse pouvait en effet être un signe du ciel, de nature à faire douter des vertus de l'empereur et rendre nécessaires des cérémonies d'exorcisme. Dans ces conditions, c'était essentiellement les phénomènes imprévus et les irrégularités qui attiraient l'attention des astronomes japonais, lesquels en venaient même à ne plus consigner les éléments prédictibles sans intérêt dans une astronomie essentiellement *utilitaire*, proche de l'astrologie. De plus, la science en Chine était liée à la politique. Le calendrier était un monopole d'État, exigeant un système officiel de calcul. La philosophie officielle, c'est-à-dire le confucianisme, qui était à la base du système politique, était, comme l'astronomie officielle, exportée pour maintenir la souveraineté de la culture chinoise sur les satellites et voisins de la Chine. Pour le Japon, au contraire, il n'y avait pas de raison politique qui justifiât d'une telle orthodoxie. Les daimyo[2] gardaient de larges pouvoirs et certains avaient leur propre calendrier, tel celui de Satsuma. De même, tandis qu'en Chine les astronomes occupaient une position dans la hiérarchie des fonctionnaires, ils étaient, au Japon, considérés simplement comme des techniciens. La liberté de choisir entre plusieurs théories au Japon était en fait aussi importante que la recherche d'un principe unitaire en Chine. De plus, le Japon n'avait pas la prétention d'imposer une influence extérieure et ses astronomes celle de croire que leurs découvertes aient à être universellement acceptées. En fait, avant le XX[e] siècle, le Japon ne croyait pas qu'il pouvait participer à la découverte universelle de la connaissance.

Le Japon était en pleine mesure de bénéficier de la science occidentale.

Dans ces conditions, lorsque l'influence scientifique occidentale commença à s'exercer, les Japonais purent rapidement changer de la science chinoise à la science européenne. Pour les Chinois, au contraire, la rencontre avec la science occidentale était dramatique. Accepter la science européenne équivalait à rejeter les valeurs traditionnelles, la rejeter revenait à rester sans défense contre les menaces de colonisation par les puissances occidentales. On ne peut manquer, en rappelant cette alternative

* Dans tout cet article, les noms propres seront donnés à la façon japonaise, c'est-à-dire avec le nom de famille en tête.

Figure 1. **Les Japonais ne sont pas que des exportateurs d'appareillage électronique ; ils en sont les premiers consommateurs** (photo A). **D'une manière générale, les nouveautés techniques sont bien acceptées et diffusent rapidement dans la société japonaise. Le patient qui est installé sous l'appareil à rayons X de l'hôpital Teishin sur la photo B est examiné non pas par le technicien figurant au premier plan mais par un spécialiste qui, de Tokyo, interroge le malade et dirige l'appareil en fonction de l'image radioscopique qu'il reçoit sur un écran.** (Cliches Fondation du Japon).

(1) Nakayama Shigeru, *A history of japanese astronomy*, Harvard University Press, 1969. Notre analyse des différences entre les attitudes chinoise et japonaise à l'égard de la science est inspirée de ces travaux.
(2) Chefs provinciaux (M. Vie, *Histoire du Japon des origines à Meiji*, PUF).

l'administration informe, coordonne, encourage mais ne décide pas seule.

	dépenses totales de recherche (DIRD) en milliards de francs courants			part de la recherche dans la production intérieure brute en %			part des entreprises et de l'Etat dans l'exécution de la recherche		part des entreprises et de l'Etat dans le financement de la recherche	
	1975	1977	1978	1975	1977	1978	entreprises	administration, universités, institutions sans but lucratif	entreprises	administration, universités, institutions sans but lucratif
Etats-Unis	157,4	220,0	223,0	2,44	2,40	2,37	67	33	44	56
Japon	42,6	69,6	80,7	1,94	1,92	1,93	58	42	59	41
Allemagne	40,0	54,5	62,4	2,23	2,15	2,16	65	35	53	47
France	26,2	33,2	37,5	1,80	1,77	1,76	60	40	42	58

Figure 2. **Les dépenses de recherche japonaises représentent aujourd'hui plus du double des dépenses françaises et plus du tiers des dépenses américaines. Le pourcentage de la production intérieure brute consacré à la recherche est plus important qu'en France, élément qui prend toute sa valeur si l'on se souvient qu'il s'agit essentiellement de recherche civile. Il n'y a pratiquement pas de recherche militaire au Japon, alors qu'elle représente environ 40 % de la recherche publique française. Enfin, au Japon, contrairement aux autres pays, les entreprises ont à peu près le même poids dans le financement et dans l'exécution de la recherche, ce qui reflète la faiblesse des transferts de l'État vers l'industrie sous forme de subventions. (Source D.G.R.S.T. Les chiffres 1978 sont des estimations.)**

où s'est trouvée la Chine il y a quatre cents ans, de penser aux changements de cap de la politique chinoise de ces toutes dernières années envers le développement scientifique et technique. Il y eut, en tout cas, aux XVI[e] et XVII[e] siècles un premier tournant que le Japon sut prendre et non la Chine.

Après un début d'enseignement de la science occidentale assuré essentiellement par les Jésuites, intervint en 1641 la fermeture stricte du Japon pour quelque deux cent trente ans. Craignant une déstabilisation politique, le gouvernement décida de fermer pratiquement le pays aux contacts avec l'étranger, ne gardant qu'une fenêtre à Nagasaki, par laquelle seuls les Hollandais et les Chinois furent autorisés à continuer à commercer sous un strict contrôle (le processus avait commencé en fait dès 1612). Grâce à cette fenêtre, cette fermeture fut à l'égard de la science loin d'être complète. En effet, sous le Shogun Yoshimune, qui gouverna le Japon de 1716 à 1745, l'étude du « savoir hollandais » fut encouragée pour des raisons analogues à celles qui avaient été à l'origine de l'importation de l'astronomie chinoise, à savoir des raisons d'utilité ; il fallait réviser le calendrier et le rendre précis pour l'agriculture, il fallait développer la médecine. Il s'agissait aussi d'utiliser les connaissances étrangères pour en tirer des avantages économiques, de nature à consolider le régime féodal qui montrait des signes de décadence ; à mesure que la menace étrangère se précisait, furent encouragées les études à fins militaires. Un point très important est que beaucoup de ceux qui étudiaient alors la science et la technique occidentales étaient d'anciens samouraïs qui, après que les Tokugawa eurent pris le pouvoir et pacifié le pays, avaient été contraints à se reconvertir du métier des armes à celui d'administrateur ou d'éducateur.

Les samouraïs qui occupaient les postes les plus importants étaient ceux dont les talents prévalaient dans la gestion, l'économie et les finances. Quant aux éducateurs, ils ouvrirent des écoles dans tout le Japon ; les gens les plus pauvres se saignaient pour y envoyer leurs enfants, car la connaissance était alors un gage de prospérité familiale. Elle est devenue maintenant le synonyme de promotion sociale. Ainsi, même si la quantité de science occidentale apprise durant la période de fermeture a été mince, le fait important est que le Japon a su utiliser cette fermeture pour élever le niveau d'éducation de sa population, avant de s'ouvrir à partir de 1850 à l'importation des sciences et des techniques étrangères, laquelle devint délibérée et massive à la restauration de Meiji en 1868. Le Japon présente ce cas unique d'avoir été en pleine mesure, dès la fin du XIX[e] siècle, d'absorber très rapidement l'acquis scientifique et technique de l'Occident ; ce n'est pas là un petit mérite à mettre à son actif.

Une connaissance utile et indispensable à l'indépendance nationale.

La première spécificité que ce survol de l'histoire scientifique du Japon fait ainsi apparaître est que la connaissance scientifique, importée de l'extérieur par vagues successives, a toujours été en premier lieu considérée par les Japonais comme une connaissance *utile*. Cela explique l'orientation sociale de nombreuses actions de recherche et développement, telles par exemple que la mise en œuvre de services télématiques à l'usage de la population dès 1964. Cette orientation sociale combinée au niveau d'éducation élevé de la population a pour effet que les technologies diffusent de façon non seulement très douce et très naturelle, mais aussi très rapide (fig. 1).

La connaissance est aussi considérée comme indispensable à l'indépendance nationale, comme cela a été le cas à l'époque de Meiji, ou indispensable à la survie économique ainsi qu'elle a été constamment perçue depuis la fin de la Seconde Guerre mondiale. L'innovation

est actuellement à l'ordre du jour en France, essentiellement parce que notre industrie commence à ressentir seulement maintenant la compétition créée par les industries étrangères, et en particulier l'industrie japonaise. Il faut se dire qu'elle l'est au Japon depuis plus de cent ans pour des raisons analogues d'indépendance militaire ou économique, et l'on ne réalise pas assez en Europe l'intensité de la tension innovatrice dans lequel baigne le Japon. Le pays est véritablement en alerte technologique permanente, à l'affût de tous les progrès, découvertes et innovations qui apparaissent dans le monde entier ou qu'il est possible de réaliser par soi-même.

Une question qui est souvent posée à ce point est de savoir comment, depuis la Seconde Guerre mondiale, le Japon a su effectuer à temps les bons choix technologiques, être efficace dans la conduite des recherches que ceux-ci exigeaient et bâtir les industries capables de fabriquer les produits qui en résultaient. Pour l'expliquer il faut tenir compte des spécificités de la société japonaise.

Pour la politique de la science, il n'existe pas dans ce pays d'instance qui ait un pouvoir de décision sur l'ensemble de la politique de R et D. En effet, les compétences sont partagées entre les différents départements ministériels concernés, et dans chacun des secteurs dont il a la tutelle, chaque département est pratiquement maître chez lui. Dans ce partage, c'est le ministère de l'Industrie et du Commerce extérieur (MITI) qui s'occupe de la recherche industrielle. Dans le cadre d'un dialogue étroit et permanent entre le MITI et l'Industrie sont définis, dans l'ordre, les choix industriels, les choix technologiques, les programmes de recherche de base, de recherche appliquée et de développement qu'il va falloir entreprendre pour atteindre les objectifs retenus, ainsi que la répartition entre l'État et l'Industrie des charges financières et de l'exécution des programmes. Cette façon de procéder garantit une certaine efficacité dans les résultats, parce qu'un ministère puissant et une industrie dynamique sont en position de porter toute leur attention et concentrer tous leurs moyens pendant le temps nécessaire sur l'ensemble de la chaîne, allant de la recherche de base à la réalisation industrielle. Du point de vue des applications, les recherches ne peuvent manquer d'être utiles, puisque les applications sont définies au départ.

Figure 3. **Seki Takakazu, un des grands mathématiciens de l'histoire des sciences qui vivait au Japon au XVII^e siècle, est le représentant d'une longue tradition de recherche scientifique théorique. Cette activité « gratuite » a été développée au Japon, indépendamment de la technique « utile », par d'autres hommes. (Doc. Fondation du Japon.)**

Avant tout, être informé.

Pour faire les bons choix industriels et technologiques, il importe tout d'abord d'être très bien informé: la collecte et l'analyse de l'information sont faites au Japon pour la plus grande partie par l'Industrie et les associations techniques et industrielles, lesquelles organisent d'innombrables groupes de travail ou commandent des études aux nombreux « think tanks » existant dans ce pays: l'annuaire des « think tanks » japonais ne comporte pas moins de cent soixante noms. Ces think tanks sont des organismes pour la plus grande majorité privés, qui réalisent sur contrat les études les plus variées, sur l'économie, la prospective technologique et industrielle, la sociologie, etc. Leur taille va de quelques employés à quelque cinq cents pour le plus grand, l'Institut de recherches Nomura. Tous ces organismes n'ont sans doute pas la même qualité, et la plupart font plus un travail de collecte d'informations que d'analyse créatrice. Mais cette collecte est exhaustive et c'est pourquoi les grandes sociétés japonaises soutiennent toutes financièrement les plus importants d'entre eux. Chaque grande société ne veut surtout pas prendre le risque d'être moins informée que les autres.

De son côté, l'administration a également ses propres instruments. Ceux-ci sont officiels ou officieux. Dans le cas du MITI, l'organisme officiel est le Conseil des technologies industrielles. Celui-ci ne comprend pas moins de neuf comités et trente-deux sous-comités, chargés de réfléchir sur la politique de la recherche et de la technologie industrielles. Les membres en sont rémunérés. Mais, parallèlement, existent de très nombreux groupes d'études officieux attachés aux

Le Japon n'est pas seulement un copieur de technologie, il a une tradition scientifique.

directions du ministère et qui jouent un rôle encore plus important. Leurs membres ne sont pas rémunérés, mais les industriels ne voudraient surtout pas manquer d'en faire partie, pour avoir accès à l'information. Ces groupes d'études, comme les conseils officiels, sont composés de spécialistes venus de tous les horizons, choisis par les directions du ministère: université, administration, industrie, presse, associations de consommateurs, etc. Une direction technique (il y en a environ vingt-cinq) peut ainsi posséder de un à trois groupes d'études officieux. Comme leurs membres, ainsi que ceux des groupes d'études officiels, sont aussi membres des groupes de travail des associations professionnelles, il en résulte un flux continuel et massif d'informations de l'administration vers l'industrie et vice versa.

Le vrai rôle du MITI.

Les choix à faire, les programmes de R et D que ces choix vont exiger, les industriels qui vont en être chargés (en dehors de la part généralement réduite qui est confiée aux laboratoires de l'État), font l'objet de larges discussions entre le ministère et ces multiples conseils. Lorsqu'un consensus général est atteint, les projets sont présentés directement au ministère des Finances, après un examen sous l'angle de la coordination interministérielle, par l'Agence de la science et de la technologie. Mais le MITI n'ira pas défendre un nouveau projet aux Finances s'il ne sait pas par avance combien l'Industrie est prête à dépenser. En fait, pour les projets visiblement très prometteurs à court et moyen termes, les différentes compagnies compétentes ont souvent engagé des recherches sur leurs propres fonds, avant même que le gouvernement n'ait pris de décision, afin d'être en position concurrentielle lors de la répartition des tâches. Pour les projets potentiellement importants mais visiblement non rémunérateurs à court terme, la politique générale des sociétés japonaises est d'y participer pour éviter que les communautés scientifique et industrielle et même le grand public ne puissent croire qu'elles n'ont pas été choisies pour raison d'incapacité. Les grandes firmes japonaises sont en effet très soucieuses de leur image de marque.

On pense parfois en Europe que le MITI est le moteur principal et le maître tout puissant de la chaîne recherche - développement - production industrielle. C'est là sous-estimer grandement la part de l'industrie japonaise dans la dynamique globale et se méprendre sur le rôle réel joué par le MITI. Le rôle du MITI, qui n'en est pas moins très important, est de faire circuler l'information, de faire se dégager une stratégie d'ensemble et de mettre de l'ordre dans l'activité parfois trop bouillonnante d'entreprises en concurrence très vive, d'être un fédérateur entre certaines d'entre elles pour les projets qui dépassent la taille d'une seule entreprise et enfin d'apporter, quand il le faut, le soutien financier de l'État. Sur ce dernier point, il faut dire que la tendance de l'État japonais n'a jamais été d'être un exécutant en R et D (sauf au moment de la Seconde Guerre mondiale). Depuis Meiji, la politique du gouvernement a été traditionnellement de transférer l'activité technologique vers l'Industrie et de la centrer sur cette dernière (fig. 2).

En évoquant le rôle fédérateur du MITI, nous touchons à une faiblesse du système japonais de R et D. C'est que si la taille d'un projet ne dépasse pas la largeur du groupe — que celui-ci soit un laboratoire, un institut de recherche, ou l'appareil de recherche d'une grande firme — il peut être organisé d'une façon parfaite et exécuté de la façon la plus huilée; par contre, tout projet qu'un seul groupe ne peut traiter nécessite la présence d'un fédérateur pour pouvoir être mené à bien. En d'autres termes, le sens du groupe et la concurrence sont trop fortes pour que des groupes différents réussissent à se fédérer par eux-mêmes. C'est pourquoi l'organisation de la R et D au Japon a souvent l'aspect d'une structure qui est à la fois localement parfaite et pleine d'imperfections si elle est considérée globalement: elle est à l'image de l'urbanisme des villes japonaises.

Un double emploi n'est pas grave.

L'imperfection la plus fréquente, tout au moins aux yeux de l'observateur occidental, est la duplication ou même la multiplication des travaux entre organismes concurrents. Alors qu'en France l'on attache la plus grande importance à la définition de la structure idéale pour l'ensemble du pays et que l'on dépense beaucoup d'énergie à constamment la définir et la redéfinir, c'est là une préoccupation qui ne semble pas compter beaucoup dans la démarche japonaise. L'on attache plus de prix à la compétition et aux considérations humaines: il est plus important de tirer le maximum des hommes. C'est pourquoi les duplications sont fréquentes, non seulement à l'échelle du pays, mais même à l'intérieur d'un groupe. Elles sont considérées comme non nécessairement mauvaises dans une atmosphère de concurrence; il est difficile d'autre part, dans une société où la face compte tant, d'écarter un chercheur réputé spécialiste d'un sujet au profit d'un autre qui lui serait supérieur — l'harmonie du groupe prime — ou encore de limiter, pour des raisons de planification, à une équipe ou à un laboratoire l'accès à un sujet nouveau: dans ce pays à l'affût de la nouveauté, toute nouveauté provoque en effet de tels engouements que ces limitations sont impensables.

Un exemple typique de duplication qui ne se serait vraisemblablement pas vu en France nous est donné par la manière dont la Régie des télégraphes et téléphones s'y est prise pour développer au début des années 1970 un grand ordinateur pour le temps partagé. Au lieu de confier ce travail à la firme qui lui aurait semblé présenter les meilleures garanties, elle a préféré diviser ses crédits entre trois de ses grands fournisseurs traditionnels, à savoir Nippon Denki (NEC) Fujitu et Hitachi, et demander à chacun de développer une machine en coopération avec ses propres chercheurs. Outre qu'elle pouvait penser tirer avantage de l'émulation entre les trois compagnies, il s'agissait aussi de ne pas gâter de bonnes relations avec l'une ou l'autre. Le résultat est que l'on pouvait voir, au moment de la livraison des prototypes au Laboratoire central, les trois compagnies se disputer les ascenseurs pour monter aux trois étages qui leur étaient réservés, les consoles de trois machines aux performances similaires!

Une tradition de la science « gratuite ».

Venons-en maintenant à la recherche fondamentale. On trouve parfois écrit — c'était encore le cas récemment dans un journal français pourtant réputé sérieux — que le Japon ne fait pas de recherche fondamentale et qu'il se contente d'industrialiser les découvertes des autres. C'est là l'affirmation la plus inexacte, contre laquelle nous tenons tout d'abord à nous inscrire en faux. Même si la connaissance scientifique a été perçue depuis toujours comme une connaissance utile, il existe une veine très ancienne d'intérêt pour la science pure. Celle-ci est apparue bien avant la première importation massive de 1868, avec la formation à partir du début du XVII[e] siècle d'une école japonaise de mathématiques (Wasan), dont le représentant le plus illustre est Seki Takakazu (1642-1708), que les historiens des sciences n'hésitent pas à placer parmi les plus grands mathématiciens de tous les temps (fig. 3). Seki en effet introduisit les notations algébriques, inventa les déterminants pour résoudre les systèmes d'équations linéaires, développa une méthode de solution des équations de degré supérieur à 2, obtint des valeurs très approchées du nombre π par la manipulation de séries d'ordre infini, etc. Le Wasan était en fait un art plus qu'une science: un mathématicien publiait un livre et posait des problèmes; un autre les résolvait et en posait d'autres, et ainsi de suite.

Le point le plus important est que moins le problème avait d'applications pratiques, plus il était prisé. C'est là un autre aspect spécifique de l'attitude japonaise devant la science qui s'observe encore aujourd'hui sous deux tendances, bien qu'à un degré moins extrême. La

Figure 4. **Tomonaga Shinichiro** (photo A), **prix Nobel de physique 1965, très sensible aux aspects esthétiques de la physique théorique, était un parfait représentant de la tradition scientifique japonaise. Le Japon n'a encore eu que trois prix Nobel et deux médailles Fields, mais nous n'en sommes qu'à la quatrième génération après Meiji et beaucoup d'esprits brillants ont été attirés par l'industrie. La photo B représente Leona Ezaki recevant son prix Nobel de physique en 1973.** (Clichés Fondation du Japon).

première est que les scientifiques japonais qui s'intéressent à la science pure s'intéressent peu à l'application : ils s'intéressent à la science pour la science. La seconde est que certains d'entre eux aiment avant tout polir certains travaux dans des domaines spécialisés, sans chercher à les relier à des ensembles plus vastes. Leur démarche évoque celle de certains artistes et est sans doute proche de celle des mathématiciens du XVII[e] siècle. Certains scientifiques ont à la fois les dons de créativité et le style de l'artiste et savent intégrer leurs travaux dans les grands courants scientifiques ; ils peuvent alors devenir les plus grands savants, avec cet intérêt pour les aspects esthétiques de la connaissance scientifique, qui relève d'un intérêt général au Japon pour l'esthétique. Le meilleur exemple est fourni par le physicien Tomonaga, prix Nobel, qui était très sensible à la beauté de la forme en physique théorique (fig. 4).

L'existence parallèle de deux attitudes aussi différentes à l'égard de la science — l'utilitaire et la non-utilitaire — a une raison historique. Ce ne sont pas les mêmes hommes qui ont été chargés des métiers d'ingénieur et de savant à la restauration de Meiji. A cette époque, il fut reconnu très vite par une certaine partie de l'élite japonaise qu'il n'était pas suffisant d'importer la technologie, mais qu'il était indispensable aussi, pour atteindre un développement analogue à celui des puissances occidentales, de maîtriser la science pure. De son côté, le gouvernement était pressé d'instituer une université de type occidental pour donner au Japon les attributs d'un État moderne. L'université de Tokyo naquit ainsi en 1877. L'université japonaise se développa peu à peu et il faut réaliser que le niveau atteint aujourd'hui par la recherche fondamentale japonaise n'est pas le résultat d'une ascension récente, mais d'une progression lente, marquée par une certaine pause lors de la Seconde Guerre mondiale. Ainsi — cela est peu connu — le physicien Nagaoka Hantaro a été le premier à proposer en 1903 et à étudier, pour l'atome, un modèle constitué par un noyau positif entouré d'électrons négatifs. Il est le premier grand physicien japonais. Honda Kotaro fut ensuite l'auteur de travaux connus en magnétisme et en physique des métaux, et Nishina, après un séjour au Danemark avec Niels Bohr, fut le premier à introduire la physique moderne au Japon en 1925. A la veille de la Seconde Guerre mondiale, le niveau de la physique japonaise n'était pas bien loin de celui de la physique européenne, notamment grâce au célèbre Institut de recherche physique et chimique (Rikagakukenkyusho ou Riken) qui était pour le Japon ce qu'était pour l'Allemagne le Kaiser Wilhelm Institute à Berlin.

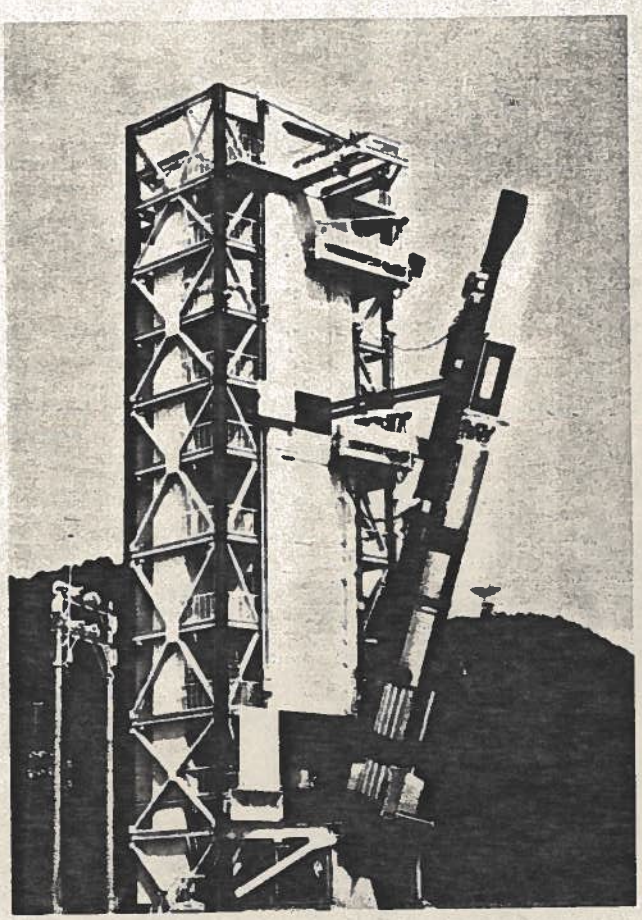
Actuellement, plus de la moitié du budget de l'État pour la R et D est absorbée par la recherche universitaire ; 772,8 milliards de yens, soit environ 15,5 milliards de francs en 1980[3]. Les parts respectives de la recherche fondamentale, de la recherche appliquée et du développement dans la recherche universitaire étaient en 1978 de 57,3, 37,3 et 5,4 % : ceci démontre au moins l'ampleur de l'effort de l'État pour la recherche fondamentale.

Où en est la recherche japonaise ?

Quelle est la qualité des résultats ? Il n'est pas aisé de prononcer un jugement de valeur sur l'ensemble de la recherche fondamentale d'un pays, car il faudrait d'abord définir les critères pour le faire. Certains, bien sûr, feront remarquer que le Japon n'a guère jamais reçu que trois prix Nobel (Yukawa, Tomonaga et Esaki) et deux médailles Fields (Kodaira et Hironaka). Mais le prix Nobel consacre souvent des travaux anciens et ce qui nous intéresse est le niveau actuel de la recherche fondamentale japonaise. Ce qui semble pouvoir être dit, après confrontation entre le jugement de l'auteur et ceux

(3) Pour la France, le total des budgets de l'Université et du CNRS en 1980 s'élevait à 7 milliards de francs.

ntre l'université et l'industrie fonctionne
n réseau complexe de relations de maître à élève,
t d'anciens condisciples, de sociétés savantes.



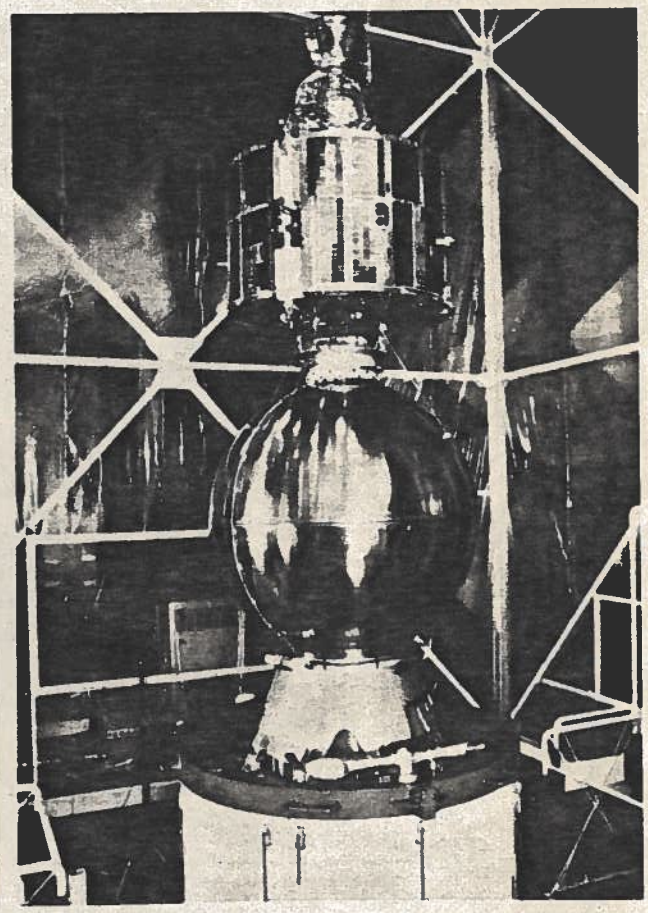


Figure 5. **L'espace n'est pas une activité de pointe au Japon. Mais cette fusée M-3H-2 et ce satellite scientifique baptisé Kyokko ont l'originalité d'avoir été conçus et lancés par... une université (Institut des sciences de l'aéronautique et de l'espace, université de Tokyo). Ils illustrent l'existence d'une recherche universitaire active qui n'hésite pas à passer de la recherche fondamentale aux applications.** (Clichés Fondation du Japon).

d'un certain nombre de membres de la communauté scientifique française, c'est que tout d'abord il existe, répartis dans des domaines variés un certain nombre de scientifiques japonais très brillants, et ensuite que la science japonaise dans son ensemble a maintenant atteint, dans un nombre suffisamment élevé de domaines, un niveau tel que l'on peut dire qu'elle compte sur le plan international. Certes elle présente encore certains points faibles mais, inversement, il existe aussi des domaines où le Japon occupe globalement une position forte. Ainsi en est-il, par exemple et sans prétendre être exhaustif, de la théorie des probabilités, de la physique statistique, de la physique des métaux, de la diffraction électronique, de la chimie des hauts polymères et de la microbiologie.

En cherchant à évaluer le niveau général de la science japonaise, comparé à celui d'autres grands pays scientifiques, il faut tenir compte du fait que la nécessité de l'effort technologique a consommé et continue de consommer un certain nombre des esprits les plus doués. En effet, il est significatif que beaucoup plus d'étudiants s'engagent dans l'étude de la technologie que dans celle des sciences pures. Les pourcentages sont respectivement de 20 % et 3 % à l'échelon national, et restent de cet ordre au niveau de l'élite, comme le montrent les valeurs des mêmes pourcentages à l'université de Tokyo, à savoir 25 % et 8 %. L'alternative pour l'étudiant japonais n'est pas tant entre la recherche fondamentale et la recherche industrielle qu'entre devenir ou non professeur. D'une part la recherche fondamentale n'a pas le caractère aristocratique qu'elle revêt facilement en France, l'enseignement des sciences donné à l'école primaire et au lycée ne prédisposant pas l'étudiant à la considérer comme telle ; d'autre part, si le professeur d'université garde un rang élevé dans la hiérarchie sociale, le prestige des grandes firmes attire en revanche un bon nombre des meilleurs esprits, la prospérité économique de ces dernières années aidant.

Il semble au total que le développement de la recherche fondamentale au Japon dépende, comme en Occident, de l'existence d'hommes capables de créer des centres d'attraction, lesquels aussi apparaissent et disparaissent. De ce point de vue, le Japon a évidemment le handicap d'être entré dans la course beaucoup plus tard que les pays occidentaux : la quatrième génération de scientifiques arrive seulement à maturité.

Quels sont les rapports entre la recherche universitaire et l'industrie ? Il faut tout d'abord observer que le partage sectoriel des compétences entre les administrations présente au moins deux avantages. Le premier est que même en cas de situation économique difficile, les crédits destinés à la recherche universitaire ne sont pas réduits par rapport à ceux de la recherche industrielle. Il ne s'agirait pas tant de réduire les crédits de la recherche universitaire que de diminuer le poids du ministère de l'Éducation par rapport à celui du MITI, ce qui, dans le contexte sociologique japonais, serait très difficile à envisager. Le deuxième avantage est que ni l'université ni l'industrie n'estiment qu'elles ont à se limiter à un ou plusieurs maillons de la chaîne de R et D. Ainsi l'université a une activité importante dans le développement et l'application des techno-

logies — les meilleurs exemples sont le développement des lanceurs de satellites par l'université de Tokyo (fig. 5), les recherches universitaires sur la fusion contrôlée, les moteurs automobiles, les robots, la biotechnologie. Inversement, l'industrie a une activité importante en recherche de base orientée : ainsi les laboratoires centraux des grandes firmes effectuent-ils essentiellement des recherches de base et publient-ils des journaux scientifiques dont le contenu ne déparerait pas les publications de facultés des sciences, pour certaines d'entre elles. La société Mitsubishi Kasei a même créé un Institut des sciences de la vie uniquement consacré à la recherche fondamentale en partie, il faut le dire, pour soigner son image de marque.

Une coordination naturelle entre la recherche et l'industrie.

Le système d'organisation sociale engendre aussi une certaine coordination interne entre recherche fondamentale, recherche de base orientée et recherche industrielle, lesquelles coexistent dans les mêmes structures et sur les mêmes lieux.

Même si le chercheur d'une firme japonaise se concentre sur la recherche appliquée et le développement, cela ne l'empêche pas pour autant de rester à l'affût de tout ce que produisent les facultés des sciences et de technologie des universités japonaises. La coordination s'effectue alors de façon officieuse mais très efficace par les relations de maître à élève, les relations entre camarades de promotion à l'université ou même au lycée, ainsi que par la participation déjà mentionnée de nombreux professeurs d'université aux innombrables organes consultatifs créés par l'administration et l'industrie. Leur position de neutralité vis-à-vis de l'une et l'autre et le respect traditionnel envers ceux qui enseignent ou ont atteint un haut niveau de compétence leur valent souvent d'être placés à la tête de ces instances. Mais l'élément moteur peut-être le plus important dans les relations université-industrie est constitué par le placement des élèves ou le recrutement des nouveaux employés. Le professeur a la responsabilité morale du placement de ses élèves et cultive pour cette raison des relations avec l'industrie. Inversement, les grandes sociétés tiennent à s'assurer les meilleurs éléments des universités. C'est pourquoi elles versent régulièrement aux laboratoires avec lesquels elles entretiennent traditionnellement des relations, des sommes de montant limité, destinées à remercier le professeur de ses conseils et des étudiants qu'il leur a adressés et en même temps garantir les mêmes conseils et la qualité du recrutement pour les années suivantes et, d'une manière générale, à maintenir une atmosphère de confiance entre la société et le professeur. Ces versements sont parfois faits en nature : équipements ou frais de voyages. Cette pratique explique le montant relativement réduit des contrats passés officiellement par l'industrie à l'université (1,35 milliard de yen en 1976).

Un autre canal très important de transfert d'informations de l'université vers l'industrie est constitué par les très nombreuses sociétés savantes et associations techniques ou industrielles, les réunions attentivement suivies que celles-ci organisent, et les journaux qu'elles publient. Que ce soit dans la communauté industrielle ou dans la communauté scientifique, il existe une circulation massive de l'information : ainsi la bibliothèque du Département de physique de l'université de Tokyo est-elle abonnée à elle seule à 151 journaux étrangers, 8 journaux japonais en langue anglaise et, ce qui est le plus intéressant à noter, 20 journaux en langue japonaise : ces derniers permettent une diffusion rapide des travaux en cours à l'intérieur du Japon qui sont susceptibles d'intéresser les physiciens. La grande presse spécialisée concourt même à la diffusion de l'information scientifique et technique : le quotidien économique Nikon Keizai ou les quotidiens industriels Nikkan Kogyo et Nihon Kogyo publient des informations scientifiques et techniques générales. L'hebdomadaire Kagaku Shimbun est plus spécialement consacré aux nouvelles scientifiques [4].

Quelles leçons peut tirer l'observateur occidental du développement scientifique et technique du Japon ? La première concerne l'organisation de la recherche au Japon ; là, comme dans bien d'autres activités humaines, les structures les plus logiques et en apparence idéales ne sont pas nécessairement les plus efficaces. Le second enseignement est que, pour le développement technologique notamment, la circulation massive de l'information est essentielle. Le fait que la société japonaise soit une société de l'information est un élément important dans la réussite économique du Japon. Enfin la troisième leçon touche à un domaine que malheureusement, sous peine d'être trop long, nous n'avons pu aborder dans le cadre de cet article, qui est celui de l'enseignement scientifique durant les cycles primaire et secondaire. Nous dirons simplement que cet enseignement a pour caractéristiques principales d'être intuitif, orienté vers le concret, et vise avant tout à ce que l'élève sache utiliser les connaissances acquises. L'enseignement japonais est vraiment démocratique en comparaison avec l'enseignement français, en ce sens qu'il permet à chacun de tirer le maximum de ses capacités.

Dernière question : jusqu'où pourra aller le développement scientifique et technique du Japon ? L'opinion de l'auteur est qu'en matière de technologie il pourra aller très loin car avec un excellent fonctionnement, centré sur l'industrie, de la chaîne recherche de base orientée - développement - production industrielle, allié à un enseignement dont les caractéristiques conviennent particulièrement à la technologie, il est possible de faire beaucoup, à condition bien évidemment d'y mettre les moyens en hommes et en capitaux, ce que semble actuellement vouloir faire le Japon. Pour ce qui est de la science pure, le peuple japonais dispose des mêmes capacités que tout autre peuple européen. Néanmoins sa population présente cette singularité d'être restée extrêmement homogène. Cette homogénéité lui a été précieuse pour le développement de la technologie, mais alors que la créativité scientifique la plus grande semble se situer là où sont les grands creusets humains, l'on peut se poser la question de savoir si, pour progresser au-delà d'un certain seuil, le peuple japonais ne devra pas à son tour se mélanger à d'autres. Il y perdra peut-être une partie de sa substance et de son génie, mais y gagnera par d'autres apports : c'est peut-être là qu'est le défi auquel le Japon devra faire face d'ici la fin de ce siècle. ■

(4) Le Nihon Keizai (L'économie du Japon) a une édition le matin et une le soir, tirant au total à environ 3 millions d'exemplaires. Nihon Kogyo et Nikkan Kogyo n'ont qu'une édition par jour et des tirages de l'ordre de 500 000 exemplaires.

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■ Terutomo Ozawa, *Japan's technological challenge to the West. 1950-1974 : Motivation and accomplishment*, MIT Press, 1974.

■ Merton Peck, with the collaboration of Shuji Tamura, *Technology*, dans « Asia's New Giant », The Brookings Institution, 1976.

logies — les meilleurs exemples sont le développement des lanceurs de satellites par l'université de Tokyo (fig. 5), les recherches universitaires sur la fusion contrôlée, les moteurs automobiles, les robots, la biotechnologie. Inversement, l'industrie a une activité importante en recherche de base orientée : ainsi les laboratoires centraux des grandes firmes effectuent-ils essentiellement des recherches de base et publient-ils des journaux scientifiques dont le contenu ne déparerait pas les publications de facultés des sciences, pour certaines d'entre elles. La société Mitsubishi Kasei a même créé un Institut des sciences de la vie uniquement consacré à la recherche fondamentale en partie, il faut le dire, pour soigner son image de marque.

Une coordination naturelle entre la recherche et l'industrie.

Le système d'organisation sociale engendre aussi une certaine coordination interne entre recherche fondamentale, recherche de base orientée et recherche industrielle, lesquelles coexistent dans les mêmes structures et sur les mêmes lieux.

Même si le chercheur d'une firme japonaise se concentre sur la recherche appliquée et le développement, cela ne l'empêche pas pour autant de rester à l'affût de tout ce que produisent les facultés des sciences et de technologie des universités japonaises. La coordination s'effectue alors de façon officieuse mais très efficace par les relations de maître à élève, les relations entre camarades de promotion à l'université ou même au lycée, ainsi que par la participation déjà mentionnée de nombreux professeurs d'université aux innombrables organes consultatifs créés par l'administration et l'industrie. Leur position de neutralité vis-à-vis de l'une et l'autre et le respect traditionnel envers ceux qui enseignent ou ont atteint un haut niveau de compétence leur valent souvent d'être placés à la tête de ces instances. Mais l'élément moteur peut-être le plus important dans les relations université-industrie est constitué par le placement des élèves ou le recrutement des nouveaux employés. Le professeur a la responsabilité morale du placement de ses élèves et cultive pour cette raison des relations avec l'industrie. Inversement, les grandes sociétés tiennent à s'assurer les meilleurs éléments des universités. C'est pourquoi elles versent régulièrement aux laboratoires avec lesquels elles entretiennent traditionnellement des relations, des sommes de montant limité, destinées à remercier le professeur de ses conseils et des étudiants qu'il leur a adressés et en même temps garantir les mêmes conseils et la qualité du recrutement pour les années suivantes et, d'une manière générale, à maintenir une atmosphère de confiance entre la société et le professeur. Ces versements sont parfois faits en nature : équipements ou frais de voyages. Cette pratique explique le montant relativement réduit des contrats passés officiellement par l'industrie à l'université (1,35 milliard de yen en 1976).

Un autre canal très important de transfert d'informations de l'université vers l'industrie est constitué par les très nombreuses sociétés savantes et associations techniques ou industrielles, les réunions attentivement suivies que celles-ci organisent, et les journaux qu'elles publient. Que ce soit dans la communauté industrielle ou dans la communauté scientifique, il existe une circulation massive de l'information : ainsi la bibliothèque du Département de physique de l'université de Tokyo est-elle abonnée à elle seule à 151 journaux étrangers, 8 journaux japonais en langue anglaise et, ce qui est le plus intéressant à noter, 20 journaux en langue japonaise : ces derniers permettent une diffusion rapide des travaux en cours à l'intérieur du Japon qui sont susceptibles d'intéresser les physiciens. La grande presse spécialisée concourt même à la diffusion de l'information scientifique et technique : le quotidien économique Nikon Keizai ou les quotidiens industriels Nikkan Kogyo et Nihon Kogyo publient des informations scientifiques et techniques générales. L'hebdomadaire Kagaku Shimbun est plus spécialement consacré aux nouvelles scientifiques [4].

Quelles leçons peut tirer l'observateur occidental du développement scientifique et technique du Japon ? La première concerne l'organisation de la recherche au Japon ; là, comme dans bien d'autres activités humaines, les structures les plus logiques et en apparence idéales ne sont pas nécessairement les plus efficaces. Le second enseignement est que, pour le développement technologique notamment, la circulation massive de l'information est essentielle. Le fait que la société japonaise soit une société de l'information est un élément important dans la réussite économique du Japon. Enfin la troisième leçon touche à un domaine que malheureusement, sous peine d'être trop long, nous n'avons pu aborder dans le cadre de cet article, qui est celui de l'enseignement scientifique durant les cycles primaire et secondaire. Nous dirons simplement que cet enseignement a pour caractéristiques principales d'être intuitif, orienté vers le concret, et vise avant tout à ce que l'élève sache utiliser les connaissances acquises. L'enseignement japonais est vraiment démocratique en comparaison avec l'enseignement français, en ce sens qu'il permet à chacun de tirer le maximum de ses capacités.

Dernière question : jusqu'où pourra aller le développement scientifique et technique du Japon ? L'opinion de l'auteur est qu'en matière de technologie il pourra aller très loin car avec un excellent fonctionnement, centré sur l'industrie, de la chaîne recherche de base orientée - développement - production industrielle, allié à un enseignement dont les caractéristiques conviennent particulièrement à la technologie, il est possible de faire beaucoup, à condition bien évidemment d'y mettre les moyens en hommes et en capitaux, ce que semble actuellement vouloir faire le Japon. Pour ce qui est de la science pure, le peuple japonais dispose des mêmes capacités que tout autre peuple européen. Néanmoins sa population présente cette singularité d'être restée extrêmement homogène. Cette homogénéité lui a été précieuse pour le développement de la technologie, mais alors que la créativité scientifique la plus grande semble se situer là où sont les grands creusets humains, l'on peut se poser la question de savoir si, pour progresser au-delà d'un certain seuil, le peuple japonais ne devra pas à son tour se mélanger à d'autres. Il y perdra peut-être une partie de sa substance et de son génie, mais y gagnera par d'autres apports : c'est peut-être là qu'est le défi auquel le Japon devra faire face d'ici la fin de ce siècle. ■

(4) Le Nihon Keizai (L'économie du Japon) a une édition le matin et une le soir, tirant au total à environ 3 millions d'exemplaires. Nihon Kogyo et Nikkan Kogyo n'ont qu'une édition par jour et des tirages de l'ordre de 500 000 exemplaires.

Pour en savoir plus :

■ Masayoshi Sugimoto and David L. Swain, *Science and culture in traditional Japan. A.D.600-1854*, The MIT Press, 1978.

■ Nakayama Shigeru, David L. Swain and Yagi Eri (Eds), *Science and society in modern Japan : selected historical sources*, University of Tokyo Press, 1974.

■ Shigeru Nakayama, *A history of japanese astronomy. Chinese background and western impact*, Harvard University Press, 1969.

■ Marc Dupuis, *La Recherche scientifique et technique au Japon*, dans « Problèmes politiques et sociaux », Série Extrême-Orient n° 361, 1979, la Documentation française.

■ T. Dixon Long, *The dynamics of japanese science policy*, dans « Science policies of industrial nation », Praeger Publishers, 1975.

■ Terutomo Ozawa, *Japan's technological challenge to the West. 1950-1974 : Motivation and accomplishment*, MIT Press, 1974.

■ Merton Peck, with the collaboration of Shuji Tamura, *Technology*, dans « Asia's New Giant », The Brookings Institution, 1976.

BIOTRON RESERCH CENTER

KYUSHU INSTITUTE OF DESIGN

In 1971, Biotron Research Center was established in Kyushu Institute of Design, Fukuoka, Japan.

The main purpose of our Biotron is to offer the controlled climatic environment for studies in ergonomics. The study of relationships between man and climatic environment forms major part of ergonomics.

The controlled climatic environmental factors are air pressure, air temperature, air humidity, illumination and air movements. It is designed not only for short period experiments but also for long period experiments e. g. a few weeks. It is a two-storied building with a total of 575m^2 in area. On the first floor we have a machinery room and the Zootron, and on the second floor the six Homotrons and the control room.

特殊生態実験室は1971年九州芸術工科大学に設立された。この実験室の目的は、気圧、気温、気湿、照度、気流を制御し、これらの環境要因が生体に及ぼす影響を研究することにある。総床面積が575m^2 の二階建で、一階には機械室とズートロンがあり、二階には、ホモトロン6室と制御室がある。

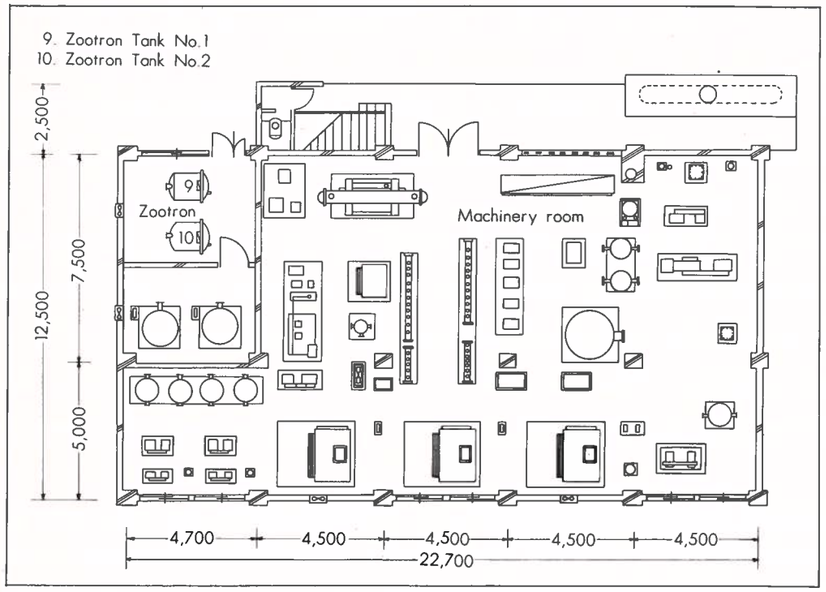

Fig. 1. 1. Plane figure of the first floor (in mm)

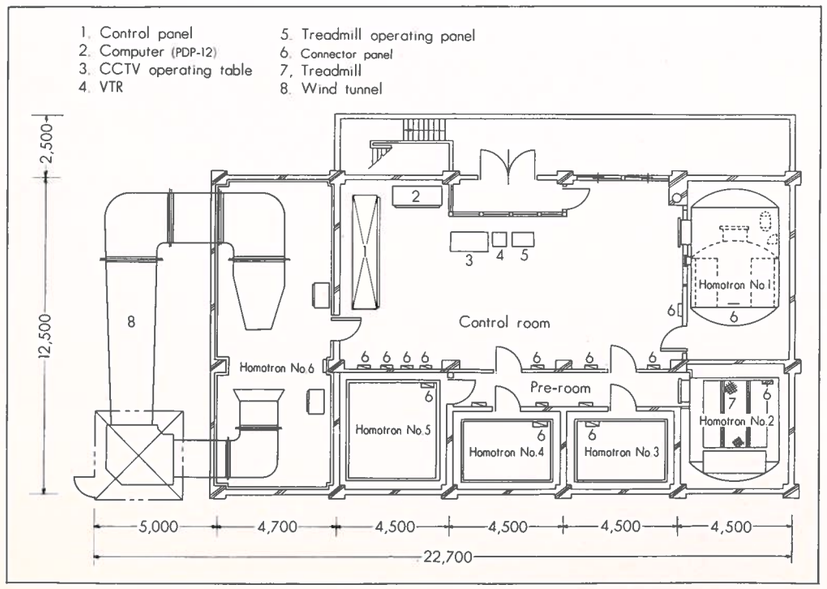

Fig. 1. 2. Plane figure of the second floor

Table 1

Name	Area m^2	Pressure kg/cm^2 abs.	Temp. °C	R.H. %	Light Lux.	Wind m/s.
The control room	94	—	—	—	—	—
Homotron No.1	34	1/4~4	7~ 25±1.0	75~7.5	—	—
Homotron No.2	23	1~1/2	−10~+50±1.0	60~80±7.0	—	—
Homotron No.3 No.4	16	—	−10~+50±1.0	30~80±7.0	0~9000	—
Homotron No.5	23	—	−10~+50±1.0	30~80±7.0	0~4000	—
Homotron No.6	61	—	15~ 30 *	40~80 *	—	0~30
Zootron Tank No.1 No.2	0.73 cm^3 (90×80×50)	1/4~4	−15~+50	20~80	—	—

* Temp. & R.H. of the wind.

Fig. 2. Inside view of machinery room

The Control Room

The control room is provided with a control panel, a digital data processing computer system (PDP-12), a CCTV-operating table and various measuring instruments. The control of air pressure, air temperature and air humidity in each laboratory (Homotron and Zootron Tank) are operated with the control panel, manually or automatically.

By the use of the digital computer, the condition in each laboratory is controlled with the responses of subjects. The control room is connected with each laboratory respectively by about 100 cables.

The data from each laboratory are received by the various instruments in the control room. The inside state of each laboratory is observable through the CCTV-camera controlled by the CCTV-operating table and is also recorded by the VTR if necessary.

各実験室（ホモトロン及びズートロンタンク）の環境因子の制御、各実験室との信号の授受、実験状況の監視は制御室で行なう。

Fig. 3. Data processing computer system

Fig. 4. CCTV-operating table

Fig. 5. Inside view of control room

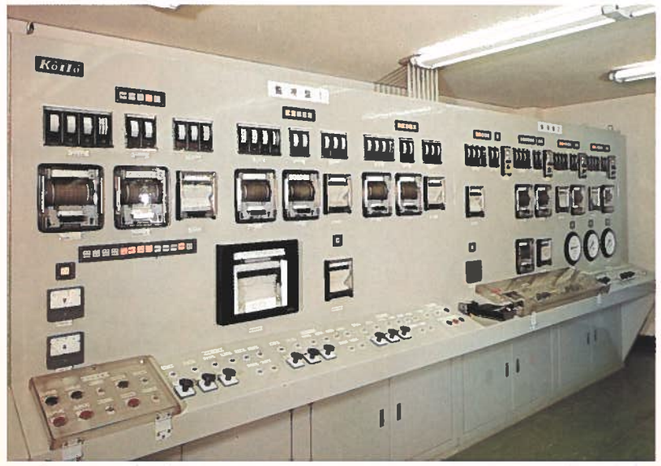

Fig. 6. Control panel

Homotron No.1

The Homotron No.1 consists of a pre-room and a laboratory. The air pressure can be controlled at will between 1/4 and 4 atm. abs. and also the air temperature can be varied. The pre-room is furnished with a compact toilet and a washbowl, and the laboratory is furnished with two beds. It is possible to get things in and out through hatch, even when the air pressure is controlled. So the subjects can remain for a long period, if necessary, and they can be observed with infrared CCTV-camera even though in dark inside.

気圧、気温を任意に設定でき、簡易トイレ、洗面台、物品投入口を備え、長期の実験を行なうことができる。

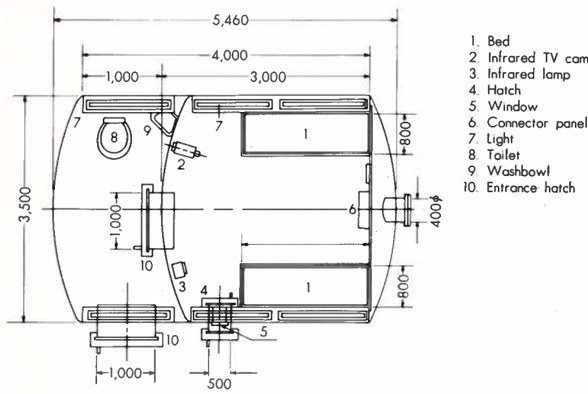

Fig. 7. Plane figure of Homotron No.1 (in mm)

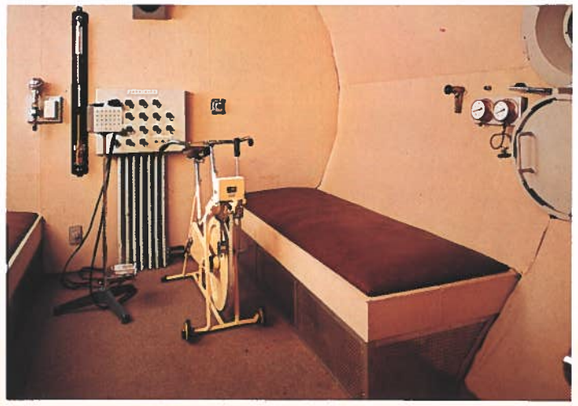

Fig. 8. Inside view of Homotron No.1

Homotron No.2

The Homotron No.2 is provided with a treadmill which can be operated either in the control room or in this laboratory. The air pressure can be controlled at will between 1/2 and 1 atm. abs., and the air temperature and the air humidity can also be varied. [The capacities of the treadmill : Speed (m/min.) 0~300, Incline (°) 0~20]

ホモトロンNo.2はトレッドミルを備え、主として減圧室として使用される。他に気温、気湿の制御も可能である。

Fig. 9. Inside view of Homotron No.2

Homotron No.3, No.4 and No.5

The air temperature, the air humidity and the illumination in the Homotron No.3, No.4 and No.5 are controllable. The No.3 and No.4 are the same in the variable range of these environmental factors, but the No.5 is a little larger than those and has a compact toilet in order to make longer experiments available. These laboratories can be linked to the control room with tubes, so that respiratory gases can be analyzed in the control room.

気温、気湿、照度の任意の設定が可能である。No.5は簡易トイレを備え、長期間の実験が可能である。

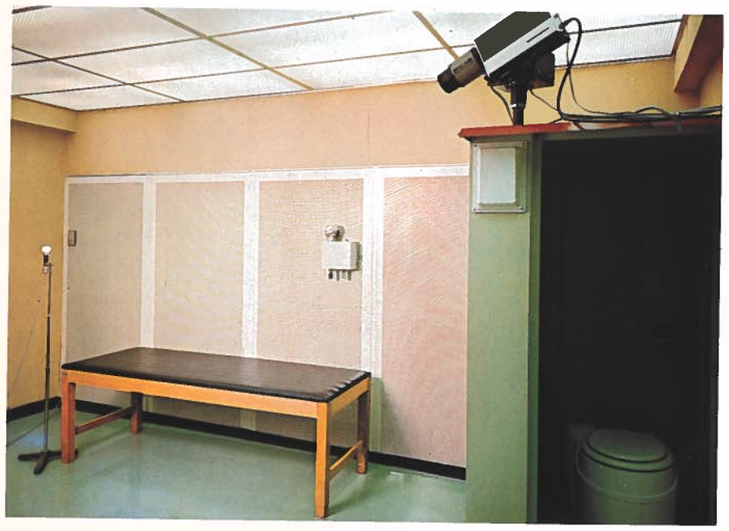

Fig.10.
Inside view of
Homotron No.5

Homotron No.6

The Homotron No.6 has a Göttingen wind tunnel with jet nozzle of 1000×1000mm at its opening, through which the wind goes into the collector 2000mm off the opening. The wind velocity can be changed from 3m／sec to 30m／sec. It is possible to control the air temperature and humidity of the wind.

ホモトロンNo.6は風洞室で、30m/secまでは整流状態が良好である。風の気温、気湿制御も可能である。

Fig. 11. Inside view of Homotron No.6

Zootron

The Zootron is used for experiments dealing with small animals. It consists of the two Zootron Tanks (No.1 and No.2) and a casual space. The air pressure, the air temperature and the air humidity in the tanks are controllable. The animals in the tanks can be observed on the CCTV-monitor in the control room and also directly through the small windows.

ズートロンは動物用実験室で、気圧、気温、気湿を任意に設定できる２基のズートロンタンクがある。

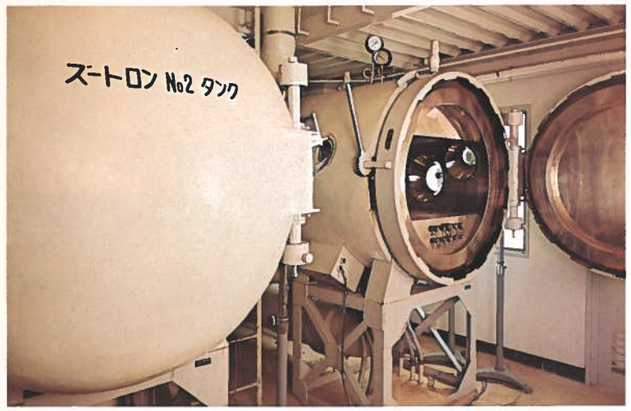

Fig. 12. Inside view of Zootron

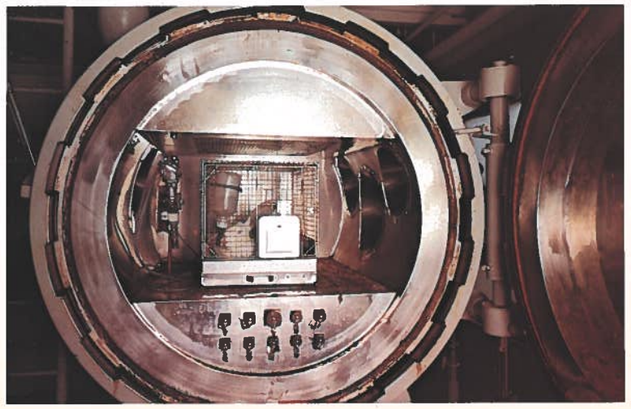

Fig. 13. Inside view of Zootron Tank

JAPANESE TECHNOLOGY TODAY

THE AUTHORS

This report is the result of the combined efforts of two of the world's leading experts on Japan's economic and technological worlds—Dr. James C. Abegglen and Mr. Akio Etori.

Dr. Abegglen is vice president of the Boston Consulting Group and a leading expert in the world of international marketing. He has been a consultant to multinational corporations in the chemical, petroleum, food and other industries and has worked with consulting firms in Japan for over 15 years.

Mr. Akio Etori is an award-winning and respected writer on science and technology, having covered these areas for over 20 years. He is currently managing editor of *Saiensu*, the Japanese language edition of *Scientific American*, and Japan's leading and most prestigious publication in this field.

Their report is based on firsthand knowledge as well as interviews with top executives in Japanese industry.

THE COVER

Symbolically resting on a tray used in the ancient Japanese tea ceremony are two of today's most sophisticated electronic components. The 4-bit one-chip microprocessor (upper right), a product of Matsushita Electric, Japan's largest consumer electronic company, is used in 6-hour VHS video recorders, microwave ovens and Technics high-fidelity components. The IC/Flexible Printed Circuit (lower left), consists of 6 IC chips in three separate packages and was designed and developed by Nikon engineers for use in their most advanced camera, the Nikon F-3, the first camera to offer an LCD viewfinder readout.

Cover photo by Phil Marco.

"Following the war, our nation actively imported technology from the Western advanced economies, devised improvements and also put into effect our own development capability. As a result, the technological level of our nation's industry, while still showing a gap in certain leading technologies, has in most sectors advanced to the top level of the world. Our nation's products have achieved a high evaluation internationally based on a high level of product technology reflected in high quality and reliability, and in precise delivery and effective after-service. These special qualities are to be maintained in the future and the general level of technology heightened.

"Still, in order to deal with various problems of the 1980's, it is not merely a matter of refining existing technology or improving the competitiveness of products. We must advance individual, creative technological development. There is some concern about this capability. However, our nation holds the largest share of patents issued by the United States to foreign nationals; since 1972, technological exports have exceeded imports in new agreements entered into; considering the current high level of technology and the considerable increase in the number of science graduates, we conclude that the potential for technological development is quite high."[1]

HOW GOOD IS JAPANESE TECHNOLOGY

This is the conclusion reached regarding Japan's technology today by the Industry Structure Council of the Ministry of International Trade and Industry in its April, 1980, report, "Vision of Industrial Policy in the 1980's." This report makes an effort to quantify Japan's relative technological position. Using an index of several factors related to technological performance, with the United States as 100, Japan is rated as only 22 in the late 1960's—about equal to France and the United Kingdom, but well behind West Germany's index of 40. Applying the same factors a decade later, Japan is rated at 50, well ahead of France and the United Kingdom, and about equal to Germany.

The Industry Structure Council also reports on a survey of views of Japanese businessmen, asking whether in 71 industry categories Japan is superior to, equal to or inferior to the United States in technology. In only two categories, both related to steel, is Japan given a superior rating, while Japan is rated inferior to the United States in 26 industries. However, Japan is seen by these businessmen as technologically inferior to Western Europe in only eight industry sectors.

Like the MITI advisory group, the businessmen see Japan's capability for development as lagging behind current technological levels, although they feel Japan is about at Western European levels in development as well as technology.

Whatever the concerns Japanese might express about the future, the accomplishment is extraordinary. If one accepts these calculations, in only one decade, Japan moved from a technical level one-fifth that of the United States to a level half that of the United States, and in the same decade from one-half the level of West Germany to approximate parity. Other calculations give Japan an even more substantial position in technology. In a recent econometric analysis, it was concluded that Japan had reached U.S. levels of technology around 1972 or 1973, and it was further concluded that a continuation of high investment by Japan relative to the United States would mean a steady shift to Japan's advantage in technology. Since the differential in investment has remained very greatly to Japan's advantage, this leads to the view that Japan now has a measurable advantage in overall technological level over the United States—and, by extension, an even greater advantage over other economies.[2]

BUSINESSMEN'S EVALUATION OF JAPAN'S TECHNOLOGY
(71 industrial sectors)

	Technological Level (number of sectors)	
	U.S.	W. Eur.
Japan superior to	2	2
Japan equal to	41	55
Japan inferior to	26	8
Not rated	2	6

Source: Vision of Industrial Policy in the 1980s, pp. 279-80.

MORE RESEARCHERS THAN GERMANY, FRANCE AND THE U.K.

There is no question that Japan's current research effort is substantial. It is not, however, especially large in research expenditure. As a percent of gross national product,

	Researchers (000) late 1960's	Late 1970's	Percent increase
Japan	158	272	+72
U.S.	550	571	+ 4
W. Ger.	72	94	+31
France	55	62	+13
U.K.	57	78	+37

Source: Vision of Industrial Policy in the 1980s, p. 278.

[1] *Hachiju Nendai no Tsusan Seisaku Bijion*. Sangyo Kozo Shingikai, Tsusho Sangyo Sho, 1980, pp. 83-4. Translated by writer.

[2] *U.S. and Japanese Economic Growth, 1952-1973: An International Comparison*. Dale W. Jorgenson and Mieko Nishimizu. Discussion Paper Number 566, Harvard Institute of Economic Research, Harvard University, Cambridge, Massachusetts, August, 1977.

JAPANESE TECHNOLOGY TODAY

Japan's research expenditures lag behind those of France and Germany and well behind those of the United States. The effort is greater when seen in terms of numbers of researchers deployed. Japan reports more research personnel than Germany, France and the UK combined—a total of 272,000, or about half that of the United States. This suggests a rather lower level of expenditure per researcher, but in any event does not indicate an exceptional effort or capability overall.

ROLE OF GOVERNMENT

There is a widespread tendency to attribute Japan's successes to the exceptional powers and abilities supposed to be exercised by the government of Japan. The field of technology is another case of this misplaced, or egregiously oversimplified, argument. Much, for example, has been made of the subsidy provided by MITI to the electronics industry for the development of very large-scale integrated circuitry. There was, indeed, a subsidy. But it totaled only $100 million over a seven-year period, divided among several producers. By the standards of R&D expenditure of that industry, and the subsidies provided by other governments to their semiconductor industries, the subsidy is trivial.

Indeed, the direct financial support of the Japanese government to science and technology is conspicuously—and perhaps even dangerously—limited. For a very long time, two-thirds of total research expenditure in Japan has been funded by the private sector. That is, while the total research expenditure by Japan is not great, the proportion provided by government is smaller than in any of the other major economies. This is consistent with the general pattern in Japan, since the total direct intervention by government in the economy is less in Japan than in the countries of the West (e.g., total taxes as percent of GNP are only about 20 percent in Japan, compared with over 30 percent in the United States and over 40 percent for most of Western Europe).

The Japanese government summarized its position recently as follows: *"... Japan's ratio of research expenditure to GNP is low at 2.1 percent (as of fiscal 1977) compared with 2.5 percent in the United States and 2.6 percent in the Federal Republic of Germany (both as of 1977). Meanwhile, in Japan the governmental contribution to the total national research expenditure also stands at only 27.4 percent (as of fiscal 1977) as against 50.5 percent in the United States and 48.5 percent in the Federal Republic of Germany (both in 1977)... As a matter of principle, technological innovation should be the job of innovators—namely, businesses themselves."*[3]

COOPERATION, NOT ANTAGONISM

Perhaps the conclusion should be that government R&D expenditure is largely wasted, and that Japan has benefited precisely because of the small amounts of government funding available for technology, support, and the pressure on the business firm to fund developments.

This too would be an oversimplification. The Japanese government has played an important role in Japan's moving to technological parity with the world. That role is more subtle and indirect than is generally seen, but no less important.

The role of the Japanese government in support of technological advancement can be seen in at least three aspects: 1/ the formulation of industrial policy, 2/ measures in support of that industrial policy, especially in indirect ways through tax and depreciation schedules and industry rationalization measures and 3/ in the earlier period through the 1960's, direct control over technological imports. Most important perhaps, the government's role in relation to technology needs to be seen in the more general context of government-business relations in Japan: a context of cooperation and mutual support rather than antagonism.

INDUSTRY'S SOPHISTICATED POLICY

Briefly, Japan's industrial policy notes that a nation's income is a result of the productivity of the nation's resources of capital and labor. It is through the improvement of the technological level that these resources are made more productive. This leads to the conclusion that the nation must steadily shift its resources of capital and labor to higher levels of value-added, to more sophisticated sectors technologically, if steady improvement in living standards is to be achieved.

Like any policy, however well-founded, Japan's industrial policy in execution often yields to some extent to political and strategic considerations. Agriculture is an example. While Japan's yields per land unit are among the highest in the world, the productivity of agricultural workers is low and product cost high. Yet the familiar political problems of conservative governments trying to deal rationally with farmers handicap Japan no less than other countries. Also, abandoning domestic food production in favor of more cost-efficient imports poses a strategic problem like that facing Japan in terms of supplies of energy and most raw materials. Thus Japan's agricultural policy is not simply economically rational, but is a complex outcome of conflicting requirements.

Yet, Japan's industrial policy is applied, usually effectively. The shipbuilding crisis of the last few years is a good example. Japan supplied about half of the world's shipbuilding market, with very efficient yards and leading technology. However, much of shipbuilding is labor-intensive and steel-intensive. With low-cost steel, and with a relatively low-cost and very flexible labor force, Japan led in such low value-added sectors as the building of tankers. This is not the kind of industry in which the resources of a highly developed economy should be invested.

HOW TO LET A DYING INDUSTRY DIE

With the collapse of the world shipbuilding market after the 1973 oil crisis, Japan was left with enormous surplus capacity. The response, painful but entirely rational economically, has been to close down 40 percent of total capacity. Government funds were made available to assist in buying back and scrapping excess capacity, but in fact only about half of these funds have been used while the target reduction of capacity was achieved. A government-approved cartel was established to allocate production, banks worked together to provide emergency funding, and the industry organized itself to plan and oversee the capacity reduction. All yards deemed obsolete have been closed, and the remaining yards are the newest, specializing in more sophisticated ship production, with the highest efficiency. The remaining shipbuilding industry in Japan should be notably productive and efficient as the market recovers.

Simple enough, one might say. Yet this is hardly the response of the other major shipbuilding economies, where funds were devoted to support dying yards rather than to closing them. It is the wide recognition and understanding of economic forces, the ability to elicit cooperation, and the ability to move toward the economically rational solution that distinguishes the policy of the Japanese government.

Note the implications for technology. In Japan, only yards less than a decade or so old will continue in production. All will be the most efficient of Japan's efficient industry. Several of the smaller companies have combined, with the resulting potential for larger-scale, more efficient operations. This raises the level of technology in the industry, but without invention, development or significant technological change.

Trade policy is another sector that is informed by overall industrial policy, and that has direct relevance to technology. The contrast with the United States is especially marked. U.S. trade policy has as its central

[3] *Economic Survey of Japan 1978/1979* Economic Planning Agency, Japanese Government. The Japan Times, 1980, p. 137.

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concern the protection of industries in trouble. One need only remember the enormous political efforts made by the United States to protect the domestic textile and shoe industries to appreciate the U.S. position. Again, as the U.S. steel industry began to encounter the inevitable result of its long failure to invest to improve its productivity, so-called orderly marketing agreements—an exercise in hypocritical protectionism—were forced on U.S. overseas suppliers. More recently, a laggard television industry was granted the same protection. Autos are now being proposed for a similar kind of shelter.

ZERO TARIFFS ON AUTOMOBILES

Japanese protectionism, leaving aside agriculture, has had an opposite thrust. Protection has been provided those industries that are in need of protection because of their newness and their fragility as emerging industries. Thus protection is negotiated for the semiconductor and computer industries, and telecommunications. Textiles are a mature industry and, in the large, not appropriate for Japan's level of development. Therefore, Japan's textile tariffs are among the lowest in the world, and textile imports increased more than 40 percent annually through much of the 1970's. Similarly, the auto industry is mature and doing well. Japanese auto tariffs are now zero, and imported cars are, in the bargain, exempted from Japan's stiff emission control requirements.

The impact on technology level is again direct. Sectors of high value-added, and high technology, with high growth potential, are afforded as much trade protection as can be arranged. This allows a nurturing of technology in the domestic market until competitive scale and sophistication are achieved. Conversely, low-value-added, low-technology, and low-growth sectors are exposed to trade competition to help force a shift of capital and labor out of those sectors and into higher technology sectors.

All of this is, however, rather far from the image of a government that possesses some special insight or foresight in its planning for technology. There is a view in the West that somehow the Japanese government has been especially clever in predicting the future of technology. This is simply not the case. MITI's so-called national research projects have not provided notable output—witness the long efforts to develop an electric car, for example. Indeed the Japanese government has been distinctly in error in its forecasts rather often, in much the same fashion as governments everywhere. The familiar story about the resistance to Sony's initial efforts to license transistor technology is an example. The government's failure to foresee IBM's third-generation computer technology is another.

It is, in fact, not the affirmative actions of the Japanese government in support of specific technologies that make its role valuable. It is rather the general policies pursued to encourage growth and encourage the move to higher levels of value-added that make the government effective. We have again an instance of the adage that it is not in the power of governments to do great good, but rather they have the power to prevent harm. Tax policies that encourage new products are an example. There was an interesting case a few years ago when the government allowed a cutback on the high commodity tax on color television if the set employed solid-state technology. Clearly, the industry moved fast to employ semiconductors.

Depreciation schedules are a better example. Fast writeoffs on new investment do not require that the government make a judgement on the merits of a particular investment. It is only required that the government understand that new investment will, by definition, tend to incorporate more advanced technology. Therefore, any tax or depreciation schedules in support of new investment in general will have the effect of raising the overall level of technology with the judgement as to the usefulness of the technology left to the entrepreneur and the marketplace rather than to a government decision. Japan's success is a powerful argument in favor of less government rather than more, in favor of the competitive marketplace rather than central planning, and in favor of policies to encourage vigorous investment rather than to stimulate consumption.

This emphasis on the indirect role of the Japanese government in support of technological advance is not to say that the role has always been so indirect. In the very earliest stages of Japanese industrialization, in the 19th century, the Japanese government took the initiative in establishing industries in a number of cases, turning them over to private investors after the initial period. (Indeed, this history no doubt explains in part the positive attitude toward government on the part of the business community today.)

More to the point of this review, during the immediate postwar period the government played a very direct role in supervising and regulating the inflow of foreign technology to Japan. The context needs brief review. Japan went to war in the mid-1930's. The long focus on military production, and the long isolation from the advanced economies, added to wartime devastation of plant and equipment, meant that in the mid-1940's, Japan was virtually bankrupt of modern technology. The military situation influenced Japan's industrial decision-making process.

THE GREAT "MAKE-OR-BUY" DECISION

Under these conditions, a critical initial decision was the classic make-or-buy decision. That was rather easily resolved; the need was so great and the availability quite sufficient to lead to a buy decision. Indeed, the need was so great that Japanese companies, out of desperation, were prepared to pay any price for foreign technology. At this point the government intervened, to regulate both the price paid and the length of the agreement—another form of price. All import of technology to Japan required specific government approval, with the government an active participant in the negotiations. This state of affairs continued essentially until the end of the 1960's, when it was judged that the marketplace could work without assistance and without too great a cost to Japan.

THE BASIS FOR TECHNOLOGICAL PROGRESS

Japan's technological progress is not the result of government programs and funding. Rather, it is the result of a highly competitive market economy, in which companies are required to invest heavily to maintain market position. This high level of investment is made possible by a high savings rate, both individual and corporate. As will be noted later, this process of competitive investment is greatly aided by a system of labor relations that greatly facilitates the investment process. An understanding of the Japanese achievement and potential in the area of technology must, however, begin with an appreciation of the very high investment levels that have characterized modern Japanese history.

Investment is, of course, the correlate of savings. It seems that there is no very clear or definitive explanation as to why a given country has had for very long periods a characteristic level of savings and investment. One might speculate that the keen Japanese sense of being a poor nation with few resources and, thereby, a need to husband available resources, explains the Japanese pattern. Thus the Americans, with a long-held sense of infinite space and resources, have a more profligate pattern of low savings and investment. In this notion, the basic attitudes eventually become embedded in tax and other policies that perpetuate the underlying attitudes.

Or again the Japanese sense of being besieged in an unfriendly world, of being isolated and subject to imperial predators, may play a part in determining savings behavior. It has also been noted that Japanese traditional, pre-industrial patterns of food, dress and housing continued well into the modern period. Thus the produc-

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tivity returns from industrialization were available for savings and investment from the lag in modernization of consumption habits.

Whatever the explanation—and the matter is no doubt multi-determined—there can be no question of the results. For a long time, Japan has had the highest levels of capital formation, and of private investment in plant and equipment, of any of the developed economies. For Japan, as for other economies, the post-1973 depression brought some reduction in the overall level of investment. But Japan's distinctive relative position remains as before.

JAPAN, A FIERCELY COMPETITIVE MARKET

It is essential to complete the view of Japan to appreciate that the Japanese economy is a market economy, and fiercely competitive. Again, like misperceptions of the role of the Japanese government, this fact is frequently not appreciated by commentators on Japan. Perhaps distance blurs corporate distinctions. In any event, the competition for market share in Japan is inexorable. This is especially true in a market economy under conditions of high growth, since it is with high growth that share positions can most readily change. The firm that fails to add capacity under conditions of high growth quickly finds itself out of the race. As growth slows, the final successful survivor is the firm that has invested most heavily and efficiently. Since growth in Japan has been especially high, it is no surprise that competitive investment has been heavy.

This sets in motion a virtuous cycle. The investments in plant and equipment, in cost improvement and product improvement, that make for success in the highly competitive domestic market, are the very factors that make export competitiveness possible. The numerically controlled lathe is an example. The high investment rate of Japanese companies, directed in part to reducing labor input and labor costs, provided a wide market for the NC lathe. The exploitation of this domestic market led to a cost and quality position in NC lathes that has given rise to an explosive growth in exports over the decade. This allows further investment and product innovation. Just as the U.S. cycle of low savings, low investment and declining export performance leads to inflation, currency crises and declining real incomes, so the inverse of the cycle is enormously rewarding.

THE INDIVIDUAL TAKES ON THE GIANT

It might be noted that the leader in this NC lathe field is not a large and internationally known company, but is Mori Seiki, a firm that was until recently small and is still privately held. The competitive, innovative thrust in Japan has tended not to come from the companies bearing the great and famous names of history. Seiko, leading the world in watch production, is a family firm. Honda, leading in motorcycle production and making an impressive run at the auto industry, is a post-war, independent success. The highly individual business philosophy of giant Matsushita Electric's founder helped it become Japan's largest consumer electronics company and is one reason its *National, Panasonic, Quasar,* and *Technics* products have worldwide respect. The list of *non-saibatsu* firms of world position is a long one—Shiseido, Pioneer, Sony, Fuji Film, Canon, Toyota, Casio. These names alone should be sufficient evidence of the degree of competition that prevails in those industries in Japan that have achieved greatest international success in technological innovation. These were not firms that began with special advantage, either with government or banks, and these were not firms that were nurtured by group affiliations. In the fast-moving sectors of high technology and consumer marketing, the seemingly favored firms of Japan have generally not prospered.

The search for the key to Japan's economic and technological success is all too often focused on the policies and plans of the Japanese government. It is a competent government, at least in its bureaucratic structure, and deserves credit. It has not earned position as the principal cause of success, however, and is best seen as facilitator and moderator. In an ultimate sense, the real cause lies in whatever it is that has led the Japanese people to be savers and investors, and to compete vigorously for economic advantage. Without the competitive thrust, investment languishes and savings lie fallow.

QUALITY—A PRODUCT OF LABOR OR AUTOMATION

It is this investment level that explains the high quality of Japanese products. There is a quite understandable tendency of many Japanese to attribute the high quality of Japanese products to the diligence of the Japanese work force. As will be noted, the work force is indeed a key factor in the move of Japan to higher technology. But the explanation of high quality lies in the investment in design, and in the investment made to take labor out of the product. That the quality of labor is high in the bargain is a great advantage. However, it is investment in automation that explains the consistent quality. Matsushita Electric's Panasert, for example, is not just a machine, but a patented process that automatically selects, inserts and affixes components so that color TV printed circuit boards—the heart of the chassis—can be assembled from start to finish without human hands.

A startling piece of evidence on Japanese quality levels was offered recently by a U.S. businessman. He reported the experience of his company in purchasing semiconductors of a particular type from three Japanese and from three U.S. suppliers.

PRODUCT QUALITY DIFFERENCES: 4K AND 16K RAM'S

	Failed Test on Arrival (Percent)	Field Failure per 1000 Hours (Percent)	Hewlett-Packard Quality Index
Japanese Supplier			
A	0	0.01	89.9
B	0	0.019	87.2
C	0	0.012	87.2
U.S. Supplier			
X	0.19	0.09	86.1
Y	0.11	0.059	63.3
Z	0.19	0.267	48.1

Source: Richard Anderson, Computer Division, Hewlett-Packard as reported in *The Economist*, April 26, 1980.

The quality of the Japanese product was high. This is of special interest because semiconductors are an instance of the U.S. producers taking the labor-intensive part of semiconductor production—the wiring of the chip—off-shore to low labor rate countries to achieve cost savings. The Japanese, handicapped by their inability to fire their labor force and by their relative lack of experience in managing foreign labor, invested heavily to automate what had been the labor-intensive part of semiconductor production. The quality differences reported by Hewlett-Packard are the result of that heavy investment.

LABOR RELATIONS AND TECHNOLOGY

High savings, leading to high investment, in a competitive economy. That is the message of Japan regarding technological advancement. To complete the pattern, however, it must also be noted that the system of employment and labor relations of Japan provides exceptional support for the introduction and diffusion of technology. Indeed, it is perhaps not too much to say that none of the Western systems of employee relations, with the possible exception of Germany's, would allow the rate and degree of technological change that has taken place in Japan in the post-war period.

The Japanese labor force has many advantages in terms of technological change and advance. It is, first of all, a highly educated labor force.

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Indeed, given the intensive nature of Japanese primary and secondary education, it may well be at the shop floor level the best educated work force in the world. Dropouts from the educational system are few, and the U.S. concern with functional illiteracy seems not to be a concern in Japan. The educational system also seems well-designed for technological matters. Earlier studies by Prof. B. Bloom at the University of Chicago indicated that Japanese secondary-level students score well above the youth of other nations in mathematics, when standard tests are administered.

The labor force is homogeneous. There are no divisions in race, ethnic background, religion and the like that can make management difficult. Further, the value system associated with the Confucian ethic—especially with regard to respect for elders and superiors—that is pervasive in Japan is very useful indeed in the context of a large corporate structure. Finally, the labor force of Japan is still fairly young, although this factor changes as the age structure of Japan shifts sharply upward over the next decades.

WHY NEW TECHNOLOGY IS NO THREAT

In terms of technological change, this labor force and its mode of organization is exceptionally supportive. In the Western system of employee relations, new technology is a real threat. By definition, it threatens job security and compensation. In the Japanese case, there is no threat. Job security is assured, and compensation is only slightly linked to a particular task. Thus, to the extent that new technology, whether process or product, will make the company more prosperous, the worker has every reason to encourage its introduction. Further, the worker has a sufficient level of education to be able to deal with the new technology. And the company, obliged to continue the worker's employment, has every incentive to train him to do so.

It is this system of employment and compensation that makes possible the worker's concern with product quality that has so impressed foreign visitors to Japan. There has recently been much interest in the so-called Quality Control Circles of Japan, where workers meet to improve product reliability and production efficiency. Attention to a particular device like the QC circle may be a case of mistaking form for substance. The important fact is that the basic system of employment in Japan is more secure and less conflict-ridden than in most countries. To an unusual degree, the potential for confrontation between management and worker has been minimized, and a considerable identity of interest has been established. On that base, QC circles and other devices can prosper. Their effectiveness in many U.S. companies might be less.

MANAGEMENT'S SUPPORT OF TECHNOLOGY

The Japanese workplace, therefore, is highly receptive to new technology, and is entirely capable of absorbing it. Factors supportive of technological change are by no means confined to the shop floor; management shares these interests. There are additional aspects of management that would appear to be supportive of technological developments in the company. First, nearly all Japanese executives are university graduates, in contrast to many of those in Western Europe. Their interest and appreciation of new technology is thereby that much greater.

The continuity of management would also seem important. Programs of research and development can be carried through and are not subject to jarring discontinuity owing to sudden changes in senior management. Nor are programs subject to plunder by a senior research or management official leaving to set up his own firm. Assuming that continuity does not stifle initiative—and for most Japanese companies it seems not to do so—this continuity must be helpful.

Two additional management issues noted are first, the Japanese company is under extraordinary pressure to grow, not simply owing to the wishes of shareholders primarily. Every person in the company sees his future prosperity as dependent on the growth and success of the firm. The firm cannot cut back the labor force, or sell a part of its business, to deal with economic downturns. It must fight its way back by internal growth—again, the theme of high investment rates, with the notion that each product group in the company must seek improvement and innovation.

And the growth must be internal. It is a corollary of the employment system that companies in Japan, or even parts of companies, are not bought and sold. Since the employee is an integral part of the company, it cannot be dealt with as a simple aggregate of assets and liabilities. Further, combining two work forces under these employment conditions is exceptionally difficult. On the whole, one might conclude that this inability to diversify the acquisition, or to cut losses by sale of a business, is supportive of solid technological change and improvement. Growth must be generic; programs must be pursued to a conclusion; innovation must come from within.

With this, Japanese management is not subject to the kind of short-term earnings-per-share pressure that characterizes much of U.S. business. The stock market tends to value growth—that is, capital gains potential—more highly than short-term changes in profitability. Further, the executive's compensation is not related directly to share price since stock options and the like are not available. All of this tends to make for a longer time horizon, and a willingness to undertake investments that offer no near term advantage but will pay out handsomely in the longer term. Thus there is both executive continuity, and a need and willingness to make long-term investments.

It is in this highly supportive context of labor and management characteristics that competitive investment is made. The potential for technological change is high from the investment level, and the opportunity for introduction is high from the nature of the relationships within the company. The result is Japan's leap to technical parity, and even leadership.

BUYING THE TECHNOLOGY OF THE WORLD

The acquisition of technology from abroad by the Japanese has been discussed. What needs to be appreciated is the massive scale of that acquisition. From 1950 through 1978, Japanese entities entered into a total of some 32,000 contracts for the input of new technology to Japan. As noted, the government played a part in controlling the cost to Japan of this importation of technology. It seems to have done so with some skill. The cumulative cost of the purchase of essentially all of the technology in the world has been only $9 billion over the period. Current U.S. research expenditure is variously estimated at about $50 billion. In other words, for a fraction of the U.S. annual expenditure, Japan closed the technology gap.

It is through these figures that one can appreciate the extent to which the workplace of Japan provides a supportive setting for innovation. One might argue that this massive flood of new technology could not have been introduced effectively into the workshops of the United States or Great Britain. The system of employment and of union relations would simply not have allowed it, even assuming a labor force of sufficient adaptability to incorporate so great a series of changes.

However, as Japan moves into the 1980's, there is widespread recognition that this is the era in which Japan must move to its own independent technological development. There are many questions as to whether Japan can succeed, and the issue needs close examination. However, it is well to note that if patents are a measure of competence, Japan seems to be doing well. The Industry Structure Council of MITI examined the pattern of the registration in the United States of patents by foreign nationals. The results are startling.

A 600% INCREASE IN PATENTS

Patents registered in the United States to Japanese have increased nearly six times in the decade from 1966 to 1976.

Japanese nationals are now the largest single foreign national source of U.S. patents. In addition, U.S. patents registered by foreigners have grown from 20 percent of total patents to nearly 40 percent of total patents in the same period, while the number of patents issued has not increased. Is this a measure of U.S. loss of research leadership? What is the potential for Japan in technological development?

RESEARCH EXECUTIVES' VIEW OF JAPAN'S POSITION

The men who manage the Research and Development efforts of Japan's major companies appear to have a realistic view of the present state of their technology. Discussions indicate a good deal of self-confidence in the present level of competitive development.

Matsushita Electric's Senior Managing Director Dr. S. Kisaka, for example, noting that *"We'd like to keep up the unique position of Matsushita as the top electronics manufacturer,"* goes on to explain that, *"We at Matsushita have distinguished ourselves by 'vertical integration' in which we produce from very basic electronic components and parts to the finished products. By producing high-quality components and parts for our own use, we can always maintain the highest possible quality in the finished products. The outstanding characteristic of our firm is that all research at Matsushita Electric has been conducted with the firm conviction that All research is for the happiness of mankind. It's because of this philosophy that we've come up with the VTR, Video Camera, theater-sized Projection TV, high-resolution TV/VTR system and other products."*

Managing Director Mr. M. Masujima of TDK Electronics Co. states a general view:

"We are certainly strong in production technology. The principal reason is the high quality of our workers. If you look at factories in the United States, Taiwan and Korea, you find no workplaces that can assemble a work force of the high quality that we have in Japan. Our engineers also are first-class, and this is one factor in our level of technology. But beyond that is the overall contribution made by the quality of our workers, of our human resources. Given the same equipment, a work force in Taiwan twice our size, or one in America 40 percent greater cannot reach our levels of output. Company scale is a factor. But without adequate motivation, such things as inspection systems will not provide product quality. Even with integrated circuits, because our Japanese work force is the most diligent, we can achieve high production levels with high quality."

OVERTAKING THE WEST

Again, asked about the basis for the overtaking of the West by the Japanese auto industry, Senior Managing Director Mr. J. Tanaka of Nissan Motors concludes that *"The greatest factor is the diligence of the Japanese. This is true not only of the way in which they work, but in the content of the work as well. It is this factor that has been our support."*

The recurring view is that the homogeneity of the work force, the high educational level of the work force, and the system of relatively strife-free work relations has been a principal factor in these companies' technical achievements to date. Managing Director Mr. T. Inoue of Victor Company of Japan takes this view:

"The Japanese production system involving career employment is a truly unique feature, isn't it. The fact of being an island nation; with that, the homogeneity of the population—because of these factors, human relations are not simply based on rights and duties. Our companies are groups, derived from this background. There is a context of loyalty. This has provided a positive environment for technological development."

Some question of the durability of these factors in the face of increasing size and complexity of companies is expressed. Senior Managing Director Mr. K. Yamamoto of Toyo Kogyo notes:

"In Japan, human relations and organization are in a single tune. However, as the organization becomes larger, and as it comes to include a number of separate sections, consensus becomes more difficult to achieve. Sectionalism begins to appear. Radical ideas, and ideas rich in originality, are more difficult to express."

While Mr. Yamamoto expresses confidence that Toyo Kogyo is dealing successfully with these problems, he raises an important issue for the future of Japan's work system.

THE COMPETITIVE AUTO INDUSTRY

In considering their situation and contrasting it with other countries', there is also a theme in the remarks of these executives that is critical of United States Management in particular. Mr. J. Tanaka of Nissan, looking to future competition, touches on this issue:

"Our future competitors are General Motors and the German auto industry. Looking at their plans, it appears that they are following closely the approach of the Japanese industry, and aiming at the Japanese industry. Since they are large-scale companies, their financial power is considerable, their technical capability adequate, and as they plan to roll us back, we will have some problems. However, in the American case, perhaps because of the structure of the companies, each single year's company results become very important. Thus, for example, when setting up a long-term plan for five years forward, company results are seen to drop because of capital requirements for the plan. And the long-term plans are not carried out. In my view, this is the major problem for America. For the sake of short-term profits, old equipment is used far too long. This is true of all U.S. industry. Even looking at General Motors plants, the assembly lines are very much out of date. They are using the methods Nissan used in 1965."

Similar themes are expressed by Dr. A. Ouchi, Senior Managing Director of Nippon Electric Company:

"Using integrated circuits as an example, America was the innovator, and in the 1960s manufactured the chip domestically, carrying out assembly in the low-wage countries of Southeast Asia. If I were an American engineer, I would probably have done the same. However, fortunately or not, the Japanese were some years behind and trying to catch up. Because we were behind in using low-wage labor, we instead sought to automate. With automation, we were able to achieve very high quality and at the same time, with appropriate machinery, achieve very low cost levels. For example, in our Kyushu plant, with complete automation we can produce at ten times the level of hand assembly, and leaving depreciation aside, have much lower costs with complete product quality.

"Labor unions are a factor in this. In the West, automation means firing people. In the case of Japan, the company gives priority to maintenance of work and therefore if automation improves the profits of the company, there is basic agreement to it. Again, in America, because long-range plans cannot be established, short-term profitability becomes the target. Thus, as with ICs, they are quick to take machinery to places where wages are low."

Rather clearly, Japan's R&D managers credit their success to good management, good labor, and a willingness to invest. There is little suggestion in their remarks of a special brilliance in planning, nor in creativity. There is a strong suggestion of self-confidence, however, as expressed by Senior Managing Director Dr. T. Sasaki of Sharp Corporation:

"In the process which proceeds from scientific concept to engineering and actual product production, I feel that in the stage of production technology, Japan generally leads the United States. Beginning with Germany and compared with Europe generally, Japan is well in the lead. However, our definitive lack is in ideas and concepts. Japan takes these from the United States, Britain and France who excel in this area, and engineers them into high levels of output."

This view of Japan as adapter and applier of imported concepts is rather widely held by Japan's research directors. According to

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Still another major company in the electronics sector, Matsushita Electric, looks at the 80's as "The Age of Information/ the Age of Energy," according to Senior Managing Director Dr. S. Kisaka. He explains:

"The coming age of information may be looked at from four viewpoints: 1) Global: With expansion of worldwide communications networks, including, among others, submarine cables, optical fibers, and communications satellites; 2) Social: CATV, multiplex TV broadcasting, office automation, and electronic transaction of business; 3) Home: Information interfaced with society through the system listed above; and 4) Personal: Pocket computer/data bank/translator, and pocket telephone. On the other hand, the coming Age of Energy will be characterized by new energy technologies, especially solar energy, and energy conservation with energy saving through more refined electronic control."

Given the general Western view of Japan, these research executives put remarkably little emphasis on government support in meeting their research and development goals. The general view seems to make a quite clear distinction between basic research and corporate research activity, and seems to indicate that government support should not be directed toward the business community. In a somewhat critical vein, Divison Manager Mr. H. Ohsawa of Toshiba states:

"Japanese companies, including my own, have insufficient concern with basic research. Their attitude is that the government, through the national universities and MITI's research facilities, should focus on this. In their view, manufacturers have the task of applying the results of the basic research."

This view is in fact generally accurate. Mr. M. Masujima of TDK was asked what he thinks about government aid to business in the research sector. He replied:

"In the case of our company there is absolutely none. Further, we do not need it. Instead of aid to companies, there should be more aid to universities and to national research institutions. It is there that basic research should be strengthened. From there, projects can be handed on to companies. It is only in that way that major results can be achieved."

Dr. T. Sasaki of Sharp, whose positive views of the level of Japanese production technology have been noted, seems to summarize the general view about the needs of the future:

"I think that each sector — government, the universities, and industry — should put more stress on encouraging science rather than encouraging scientific technology. Industry can amply develop technology. However, for the encouragement of science, scientific research budgets are insufficient. A cause of limited government aid is the fact that there is no military funding. To balance the lack of funding, I think it is necessary to have industry-university cooperation. For example, required facilities might be jointly established at the companies. University staff can make good use of the facilities, and at the same time, more effort will be needed in support of basic and general concepts for which equipment is not necessary."

These views are those of executives in companies in which the directions and potential for further technological development can be fairly clearly identified, in the near term at least. But not all industries have a promising future. It is useful to recall the general view in Japan that the nation grows not only by pursuing promising technologies and growth, but by concurrently allowing the marketplace to diminish the role of industries that have reached technological maturity. Steel is just such an industry. Despite the fact that Japan is the acknowledged leader in technology and in production cost position, steel imports into Japan are growing rapidly, and new sources of steel products are clearly emerging as effective competitors.

Technological change and economic growth are the shift of resources from mature industries to growth sectors with higher technological levels and therefore higher levels of value-added. The Japanese response to pressure on the steel industry is therefore of special interest. Dr. T. Ikeshima, Executive Vice President of Sumitomo Metal Industries offers a point of view:

"Thinking only of the steel industry, the advance of the developing countries as competitors is not pleasant to contemplate. However, from a different point of view, a widening of the GNP gap is certainly not a plus in terms of the international environment. As countries raise their living standards, and increase their use of steel, the increase in demand will lead to a growth of their steel industry. At the same time, there will also be a requirement for higher value items, and the supply of these will be a plus for Japan. We should view the issue in this manner; we Japanese have been trained to see the issue in this way.

"Earlier we studied America, and we can now be considered to have surpassed America. However, that is because of America's own stagnation. I feel that when humans are more or less hungry, they should be pursuing some goal. As they gradually begin to reach their objective, they strive to pull ahead as leaders. In that view, we intend to support the technical efforts of other countries as much as possible, and in as many places as possible. The most eager are Taiwan and South Korea. However, if leaders and workers do not really share common interests, great difficulties result. Both countries depend on imported raw materials, in the same way as Japan. We hope they will expand and develop."

THE ISSUE OF INNOVATION

In technology, as in so much else related to their economy, the Japanese have caught up. By all indications, their technology is at the highest levels.

From flower-mat making, to import substitution, to industrial competence of the highest sort, Japan is the first non-Western society to have traveled the entire distance from handicrafts to technical eminence. It will be some time before the world, and the Western world in particular, entirely adjusts to this change.

Japan too is having some difficulty adjusting to the change. Trade and investment policy, appropriately protectionist earlier, have changed only in the past decade. Perhaps the most difficult adjustment though is in the selection of further goals. Having caught up in so many areas, what targets are next?

"...(A) major requirement for the stable growth of the Japanese economy in the future is the acceleration of technological innovation. The chances for our success in overcoming the energy problem, for one, crucially depend on it. There are more reasons why we must accelerate the development of new technology. First, the level of Japanese technical accomplishments has generally caught up with those of the major industrial countries of the West. Also, the level of income in this country... has rapidly improved so that it is close to parity with the Western countries.

"If only in the interest of the international division of labor, therefore, Japan is faced with a pressing need for developing a more knowledge-intensive type structure of industries in a short time. We also need a technology of our own if we are to improve the living environment, given the "high-density society" we have in this country. All these considerations ... underscore the importance of technological innovation, especially in the development of technology of indigenous origin."[4]

To date, the technical accomplishments of Japanese industry have been focused on what might be called the

[4]*Economic Survey of Japan 1978/1979* Economic Planning Agency, Japanese Government. The Japan Times, Ltd., Tokyo p. 203.

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middle-range of technology—watches, cameras, autos, and home entertainment products. Japan has a minuscule aerospace industry, only a modest position in atomic energy developments and a distinctly secondary position in computers and computer-related areas. Japan's successes have been greatest in mass-produced items, in process engineering and in quality control. The successes have been considerable and should not be minimized in any way, but are in a sense a measure of the task of moving to new technology in terms of invention and basic innovation.

In considering whether Japanese industry can, in fact, move to a new level of technological output, the initial questions usually relate to whether the pattern of high savings and investment, of supportive labor relations and work force quality, and of stable and competent government can be maintained. These are perhaps not the critical questions. The crises of the 1970's provided a severe test of the durability of these aspects of Japanese society and industry. They have survived the test very well indeed. It is reasonable to expect their continued survival well into the future, barring some external catastrophe.

A question that must be asked concerns the ability of the Japanese to innovate in the industrial sector, in the sense of creating new products and systems. There can be no present answer to the question, since it only now arises as an appropriate issue. That the Japanese are creative is clear enough. The existence of a distinct and unique culture, with special art forms and living styles, is surely testimony to creativity. Individuals like Tange in architecture, Munakata in art, Kenzo in high fashion, and Mishima and Kawabata in literature are creative by any measure and in every sense.

The question remains, however, as to whether in a corporate context, with emphasis on group values and group-centered behaviors, the same degree of creativity can be fostered. Japanese cliches like *"The nail that sticks out gets hammered down"* are folk-wisdom testimony to the pressures to conform to group expectations. These pressures must be oppressive to the development of innovation.

Yet it can also be argued that a supportive group context allows creative risk-taking because the costs of failure are less extreme than in the more punishing climate of work relations in the West. It can also be held that the processes of research and discovery in modern industry are in their nature more a group activity than an individual activity. The model of a Thomas Edison tinkering alone in a lab is hardly a suitable model for development work in aerospace or next-generation semi-conductors.

A related and often discussed question is whether the Japanese suffer some special handicap in terms of the development of software and of systems technology. As with the issue of industrial creativity, the answer will have to await the outcomes of the next years. Certainly Japanese competence in mathematics is generally high. Clearly, Japanese investment in this area has been relatively limited from the absence of large-scale government programs, as in the United States. And, in a sense, the need for development in this area arises only after the hardware has been put in place, and is therefore in any event the next stage of concern for the Japanese.

Another major question about Japan's ability to deal with the issue of developing unique technology is set out by the Economic White Paper. *"... What matters is creativity in the private sector. But the government also has as large a role to play not only in sharing research and development expenditure with private industry but in improving the educational and research institutions at large."*[5]

Just as there has been general agreement that the quality of primary and secondary education in Japan is very high, so is there general agreement that the financing and facilities for higher education in Japan are at a low level. Further, graduate training is largely for academic careers, and the system of compensation of the major companies offers little incentive to undertake graduate study before entering the work force. Japan's companies have made up for these deficiencies by in-house training programs for the most part. The question remains as to whether Japan will produce a sufficient supply of highly trained specialists. The current efforts to establish a research-centered university and community near Tokyo are a recognition of the need. The slowness of development of that complex is a measure of the problem.

Apart from government support to education, there is the more general question of government support to research. Substantial military and space budgets have provided a subsidy base in the United States for the development of jet engines, aircraft, electronics, special metals and other leading-edge technologies. There is little prospect of Japanese industry getting this kind of base support. No doubt tax concessions and very fast depreciation schedules will be employed, and semi-governmental units like the Nippon Telephone and Telegraph Corporation and the utilities companies will provide indirect financing. But for very large-scale projects more direct government financing is likely to be needed. Japan has not yet established a system for such support.

Thus there are substantial and unresolved questions about Japan's ability to become a major source of new technology for the world. Yet perhaps the factor that makes a positive outcome most likely is the clear recognition by the Japanese government and business community that there is an overriding need for innovation, and a wide agreement that the national interest requires that major efforts be concentrated in this area. Along with this agreement on goal, there is a generally high level of self-confidence about the ability of the Japanese economy to meet its goals.

The period since the 1973 oil crisis has been for most of Japanese industry a period of consolidation and regrouping. The success of the effort, measured by relative economic growth currently, international competitiveness and improved corporate results, has led to a degree of self-assurance not previously visible on the part of the Japanese economic community. The next goal is innovation. It would be an imprudent gambler who would bet against their reaching the goal. And, in fact, a shift to significant innovation in science and technology would be simply a natural and logical extension of Japan's economic development until now. For the world, the prospect of Japan as a major source of capital and as a major source of technology over future decades, should be an encouraging one.

5 *Economic Survey of Japan 1978/1979.* Economic Planning Agency, Japanese Government. The Japan Times, Ltd., Tokyo. p. 203.

The publisher, authors, Ted Bates & Company, coordinators of "Japanese Technology Today," would like to acknowledge the important contribution by the members of the international business community whose messages appear on these pages:

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16 Septembre 1976

Monsieur le Docteur K. Seki

Chargé de recherche du laboratoire
de Physiologie de la Plongée
JAMSTEC
2-15 Natsushima-cho
Yokosuka-shi
237 (Japon)

Mon cher collègue,

J'ai été très heureux de trouver sur mon bureau, à mon retour de vacances, votre magnifique présent qui symbolise si bien le raffinement de votre pays. J'ai été d'autant plus touché que je crois comprendre qu'il est l'oeuvre de Madame votre mère, ce qui naturellement augmente singulièrement sa valeur à mes yeux.

Je vous prie de lui transmettre mes respectueuses salutations ainsi que mes remerciements.

J'ai aussi reçu votre lettre du 9 Septembre et je me suis réjoui de savoir que vous aviez été nommé Chargé de recherche du laboratoire de Physiologie de la Plongée de Jamstec. Il s'agit pour vous d'une nomination bien méritée et je suis persuadé que vous y ferez de l'excellent travail.

Il est bien évident que je serais heureux d'être au courant de vos travaux. Nous ajoutons le plus grand prix à la collaboration entre le Japon et la France, étant donné la valeur des travaux de l'Ecole japonaise de Physiologie du Travail et Ergonomie.

Je vous demande de bien vouloir transmettre à cette occasion mes meilleures salutations aux collègues japonais que j'ai la chance de connaître, et en particulier au Docteur Kogi.

Veuillez agréer, mon cher collègue, l'expression de mes sentiments très cordiaux ainsi que mes félicitations renouvelées.

A. Wisner

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Dr. Kunihiro SEKI
JAMSTEC
2-15, Natsushima-cho,
Yokosuka-shi,
237-JAPON

Yokosuka le 9 Septembre 1976

à Monsieur le Professeur A.WISNER
22, rue Emile Dulois,
75014-PARIS
FRANCE

Cher Monsieur le Professeur

A partir de 1° Septembre, Nommé CHARGE DE RECHERCHE de Laboratoire de Physiologie de la Plongee de JAMSTEC. Je m'empresse de vous en informe. Quand Je restais à Marseille, que Je tiens à Vous en remercier. D'autre part, Je serais heureux si vous vouliez bien m'aider de vous conseils. Vous avez acquis une très grande experience sur laquelle J'aimerais beaucoup pouvoir compter.

Veuillez recevoir, cher Monsieur le professeur l'expression de mes sentiment respectueux et distingues.

K.SEKI

Monsieur le Professeur WISNER.

CHANGEMENT DE LABORATOIRE
DE Monsieur SEKI Kunihiro

Son séjour en France se terminant fin Août 1976, Monsieur Kunihiro SEKI a le plaisir de vous communiquer ses nouvelles adresses au Japon.

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Je vais partir le 19 août 1976 de PARIS à Tokyo. Je vous offrirai un petit souvenir de Japon. Je n'oublie pas votre très bon dirigeé. Je vous remercie encore une fois.

très Amicalement

SEKI

ORGANIZATIONAL STATUS OF 'NINGEN-KŌGAKU' (ERGONOMICS) RESEARCH IN JAPAN

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INTRODUCTION

Ergonomics or human factors engineering is called 'ningen-kōgaku' in Japan. 'Ningen' refers to human and 'kōgaku' to engineering or technology. This term may imply two features. Engineering demands optimized systems solution, whereas it is claimed that as one of human sciences individual work and life should be within the scope of study.

These two features emerge from a brief historical sketch. The word 'ningen-kōgaku' was first coined in 1921 into a book on motion study by K. Tanaka. In the same year, the Institute for Science of Labour was founded in a spinning mill. There physiologists and psychologists took part in the study of effects of work load and environments and tried to praise biological principles as their standpoints.

The end of the war marked revival of the work-science. However, since engineering psychology had not been strong, the human factors concept was introduced rather as a new area of engineering that called from its side for cooperative work of medicine and psychology, the stress being laid on the design of man-machine units. The first national conference on ergonomics was held in 1963. In 1964 the Japan Ergonomics Research Society (J.E.R.S.) came into existence. There have been so far 10 national conferences on ergonomics, as annual meetings since 1967. The past one decade saw formation of 'ningen-kōgaku' groups on a large scale, mainly oriented to equipment and work-place design. Systems engineering tendency is stronger than ever, but few groups seem to have succeeded to organize real cooperative work of engineers and life scientists.

ORGANIZATION

The main disciplines represented in the society are engineering, psychology, physiology/medicine and industrial design (Table 1). 49 % are working in universities, 12 % in research bodies and 31 % in industry.

Table 1. Disciplines represented in J.E.R.S. (1969-70).

Disciplines	Registered members (1143 persons)	Active members (168 trustees)
Engineering	32 %	23 %
Psychology	13	27
Medicine	14	22
Physiology	8	13
Industrial Design	11	2
Apparel Design	11	4
Others	11	9

The contributors at the 10 national conferences distributed among about 50 university departments, 18 research establishments, 16 enterprises and 4 hospitals. Five research groups each of which contributed more than 5 % of total papers at the last five conferences are Industrial Products Research Institute, Railway Labour Science Research Institute, Architecture and Industrial Design Departments of Chiba University, Administrative Engineering course of Keio University and the Institute for Science of Labour (I.S.L.).

There follow courses of machine engineering, industrial management or biomedical electronics in universities, national aerospace or aeromedical laboratories, living environment laboratories of women's colleges and industries of automobile, computer or iron and steel.

Table 2. Distribution of Research items reported at the J.E.R.S. conferences (344 reports, 1963-69).

Research items	Percentage
Perception and motor skills	20 %
Posture and work space	14
Human control and systems design	12
Aerospace and vehicle design	12
Work load and fatigue	11
Controls and displays	10
Environmental factors	7
Anthropometry	4
Others	10

Table 2 demonstrates the scope of J.E.R.S. activities.

There have been numerous anthropometric projects in institutions like Products Institute and others. About 200 basic anthropometric items were standardized in 1970. Posture, static load and work-space studies are performed by I.S.L., Railway Institute and other vehicle or furniture design groups. In the design of seats Chiba University is especially active.

The area of visual perception and display is investigated by many psychological and technological laboratories. The area may be extended to acquisition of sensory-motor skills and attention. Control/display relations are studied mostly in aviation and vehicle fields. Automobile driving and traffic safety have generated a volume of researches in most of specific institutions mentioned. Design of consumer products also comprises a substantial area.

The studies pertaining to human control analysis and systems design are being conducted by technologists as in universities of Tokyo, Osaka, Keio and other research institutions. Systems design projects seem, however, to show still reluctance to make the work 'multi'-disciplinary.

Vigilance or monotony is approached by work scientists. They are also involved in fatigue studies using a variety of tests and polygraphic technique. Mental load assessment belongs to their current topics. I.S.L. is also known by its abundant calorimetric data of industrial workers. Public health people and industrial physicians contribute much in regulation of environmental conditions. Many physicians are also actively involved in human factors work. Effects of vibration or acceleration are also the interest of specific engineers.

As a sample of work-science activities, brought-in research items of the I.S.L. (Table 3) show that studies on work load and environmental conditions comprise major areas. Most of them are concerned with such actual problems as adequate communication time rate for air traffic controllers. Increase of items on on-job disorders is obviously relevant to work design.

Table 3. Research items entrusted to the Institute for Science of Labour

Research items	1949-55 (615 items)	1963-69 (725 items)
Work capacity and job adjustment	11 %	5 %
Work load and fatigue	31	23
Environmental conditions	17	27*
Prevention of diseases		
(a) Intoxication and pneumoconiosis	16	21
(b) On-job disorders and accidents	8	14
Food and nutrition	5	3
Socioeconomical conditions of work and life	12	7

(Purely diagnostic and measurements activities are excluded.)
* Including air pollution problems of 4 %.

Institutions like I.S.L. undertake part of the consultant work, but in general there are few specialists firms of consultants in the human factors field.

Inter-enterprise human factors groups are found in automobile, shipbuilding, camera, furniture, iron and steel industries. Japan Automobile Research Institute and Maritime Labour Research Institute are sponsored by the related industries. Research Sections of the J.E.R.S. offer also industrial application work in apparel design, road-sign, underwater or aviation fields.

PUBLICATION AND TRAINING

The society's journal, Jap. J. of Ergonomics, is one of main publications for research results, but many contributions are found separately in various specified journals as J. Sci. of Labour by I.S.L., Ind. Engineering, Operations Res., Jap. J. of Ind. Health and Journal of Soc. of Automotive Engineers. Reports of independent institutions are also important sources.

Nearly 10 textbooks with titles of 'ningen-kōgaku' have appeared. But the need for a comprehensive textbook is felt. A checklist for work design was worked up by a special committee of the society in 1967.

For general undergraduate machine engineering or design students, 40-60 lecture hours are often spent on human factors. The number of engineering institutions offering courses with human factors emphasis is increasing. National Kyushu Institute of Design offers a course in ergonomics. (In institutions preparing psychologists, physiologists and other human biology specialists usually little attention is paid to human factors, with a few exceptions.) But in these institutions educational programs are not uniform. There grows slowly an awareness of the need for more training in human factors work. For people in industry, only some short training courses are held and training depends generally on apprenticeship level.

CURRENT TREND AND CRITICS

The difficulty of human factors work seems to lie both in the understanding of man's dynamics in his working environment and in multiple data analysis.

In the first place, we find no universal agreement on ergonomic criteria. There are criticisms that human factors work is too narrow to solve design of work as an individual social activity. Systems approach often ignores social and ecological conditions in which work is done, and the work-science, with its integrated load assessment, is not in a position to present a clearer model. Symbolic is the assessment of multiple data. In the face of a heap of multiple charts it is asked what an ergonomic approach is.

In 1969 an ergonomists committee acted as a technical 'umpire' of a labour-management confrontation of locomotive engineers and proposed the single-engineer plan. But criticism arose among work-science circles that there is little scientific basis to back the committee report in view of dense train operations with frequent night shifts and numerous level crossings. The dispute was finally settled by the exclusion of midnight and other particular trains, but it called for grave reflection on an 'ergonomic' judgment.

Secondly, we know technical optimization is often rejected if it lacks cultural considerations. As an example, recent computerization of the sales of American magazines caused a bulk of complaints among readers. People felt insulted when requested every month for the subscription fee for the next term. The firm had to amend its project also for other reasons of the kind. Another example is people's persistence to classical unit of land area, tsubo, which is based on a two-mat size of 3.3 m^2. A mat of 91 x 182 cm is a practical and comprehensible unit in Japanese daily life. Now that people are compelled to indicate only by m^2, they compute in mind dividing by 3.3 to get a concrete image of the size.

Thirdly, more severe criticism is that the fixation of working patterns results from an ergonomic solution. The consequencies are often easier but fragmentary, comprehensible but skill-killing work. Monotony is a typical difficulty. A work that does not exclude the advancement of individual creative skill will be future problem. An attempt is being undertaken by 'ergologists' group through understanding of ecological and biological factors in human routines of work and life, as a cooperative work of work-scientists and anthropologists. Such measures as re-appraisal of dynamic physical activity, alternation of complex but not-discouraging tasks, appreciation of autonomy in work and others would be areas for consideration.

There is strong hope in us that the exchange of ergonomic work should not be limited to human factors data and techniques only, but extended to this actual subject of 'the human and technology', being aware of different cultural background.

Experimental Study on Mental Strain of Navigators — I

- Physical and Mental reaction of Navigators — during sea navigation watch

操船者の緊張感に関する実験的研究 — I

航海当直中の心身反応について.

Annual Report of Japanese Navigation Association.
December 1967

T. Kuroda.

操船者の緊張感に関する実験的研究—Ⅰ.

航海当直中の操船者の心身反応を中心として

黒田　隆*

Experimental Study on Mental Strain of Navigators.—Ⅰ.
—Physical and Mental reaction of Navigators
during sea navigation watch.—

T. Kuroda

Abstract

Using Ergonomics method, the writer attempt to examine the dynamic aspect of mental Strain of Navigators during sea navigation watch.

The results are as follows:

1. Physical and mental reaction of Navigators are caused by following stimuli, for example, searching L't Ho,. alternation course and existence of other vessels.

2. Pattern of P.G.R. shows extreme difference between open sea and narrow channel, skilled and unskilled, approaching pier and sea going.

3. C.T.G. rate, in good triffic condition, shows regular fluctuation, but in traffic convergency or risk of collision shows acceleration.

1. はじめに

筆者は既報〔1〕において，水路条件と操船者の緊張感との関係を考察し，緊張感の程度とそれを誘発する要因を幾分明らかにすることが出来たが，このような主観的・静的な研究では緊張感の実態を一面的にしか捉えられない憾みがあつた。緊張感の主観的評定を何らかの客観的計測でチエツクすること，生々しい動的データーを集収することが必要であつた。以上の理由で，筆者はこの数年機会ある毎に実船実験を行なつてきたが，本稿ではその中から数例を選び，操船者の緊張感の実態を示す事例として紹介しようと思う。

2. 実験の概要

航海当直中の操船者は継起的に加えられる刺戟の下で適切な処置（反応）を行ない，船舶を安全に運航しなければならない。この刺戟—反応の関係を図式化し，これと精神的負荷とを対応づけた時，操船者の緊張感がどのような様相を示すかを先づみようとした。これが今回の研究の目的である。

そのために筆者は諸家の人間工学的研究〔2〕〔3〕を参考とし，実験目的にかなうと思われ

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る方法を次の如く考えた。

(1) 動作分析——Barnes〔4〕に範をとり motion time study を採用。そのために必要な Thirblig を千原氏の研究〔5〕を参考として試作。これを用いて5秒毎の動作記録を行なう。

(2) 環境観察——反応を誘発する船橋内外の刺戟をテープレコーダに録音記録する。

(3) P.G.R. 測定——心的反応の一つとして精神反射 (Psycho Galvanic Response) をとる。計器は竹井機器製精神反射電流測定器ＰＴ－4型。

(4) C.T.G. 測定——心的反応の一つとして心搏数 (Cardio tacho gram) をとる。計器は三菱 1 channel 医用 Telemeter ＰＴ—110型およびフクダ医療製無線搬送心電計ＲＣ－１Ａ型。

(5) 内省報告——実験直後，アンケートおよび自由記述により緊張感に関する内省を聴取。

(6) その他——①平静心搏数の測定。②実験前後のフリツカー測定，③パーソナリテイ・テスト。

以上の実験方法を航海当直作業を妨げないよう充分配慮しながら用いた。

事例として示す実験の状況は表のとおりである。

表 1. 実 験 事 例 一 覧

事　例	実験時期	実　験　船　舶	被　験　者	水　　域
1	39. 7. 4.	深江丸（D.W. 150㌧）	Y教官，M学生	三原瀬戸東入口附近
2	40. 7. 6.	〃	A学生	三原瀬戸
3	41.11.10.	K社N丸（D.W.11,000㌧）	Capt. 20. 30.	神戸港，友ケ島水道，土佐沖
4	39. 3.26.	深江丸（D.W. 150㌧）	T教官	三原瀬戸
5	41.11. 8.	K社N丸（D.W.11,000㌧）	Capt.	来島海峡西水道
6	41.12.31.	I社N丸(D.W.132,334㌧)	Capt.	Singapore St,
7	42. 4. 8.	〃	〃	〃

3. 実 験 の 事 例

3. 1. P.G.R. 反応の事例

緊張を要求される場面では自律神経系が刺戟されてＰ．Ｇ．Ｒの増すことが生理学的に知られている。これは精神的発汗によつて生ずる反射現象である。実験に用いる時は左手２本の指先に電極をとりつけ有線で反射を記録する。コードをひきづるため操船者の行動を束縛する難があり，従つて昼間の実験のみに使用した。

事例１．熟練者と未熟練者のＰ．Ｇ．Ｒ．反応（図１参照)。

これは備後灘百貫島をすぎて三原瀬戸東入口大浜埼に向うところ，学生が教官の指導をうけながら当直している状況である。学生は島や岬が重り合ってどこが水路の入口かわからない上に横切船や同航船があり非常に緊張している。Ｐ．Ｇ．Ｒ．は次々におこる刺戟に反応して下がらない。これは不安・焦燥反応と解釈出来る。これに対し教官は落着いており必要に応じて適宜アドバイスする程度でＰ．Ｇ．Ｒ．反応は殆んど平静である。

事例２．同一人について水路の広狭によるＰ．Ｇ．Ｒ．反応比較（図２参照）

指導教官にたのんで船橋から立去つてもらい全く一人で学生に航海当直をさせた例である。進路上を妨げる漁船の数は殆んどかわらないが，狭い水路では反射が極めて頻繁で広い水路ではそ

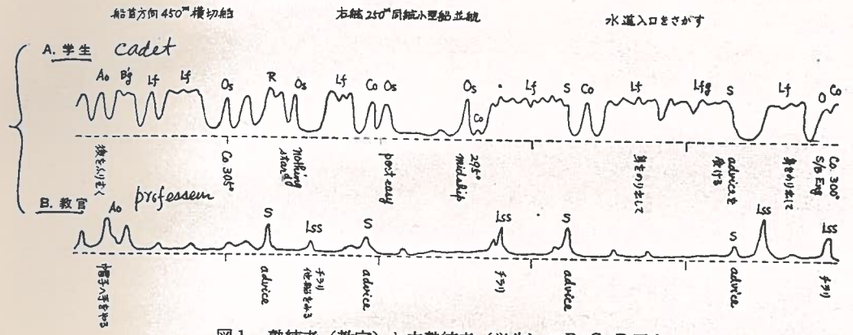


図１　熟練者（教官）と未熟練者（学生）のＰ．Ｇ．Ｒ反応

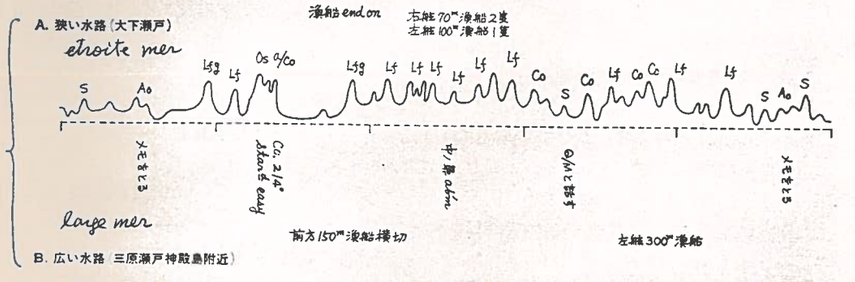


図２　同一人について水路の広狭によるＰ．Ｇ．Ｒ反応

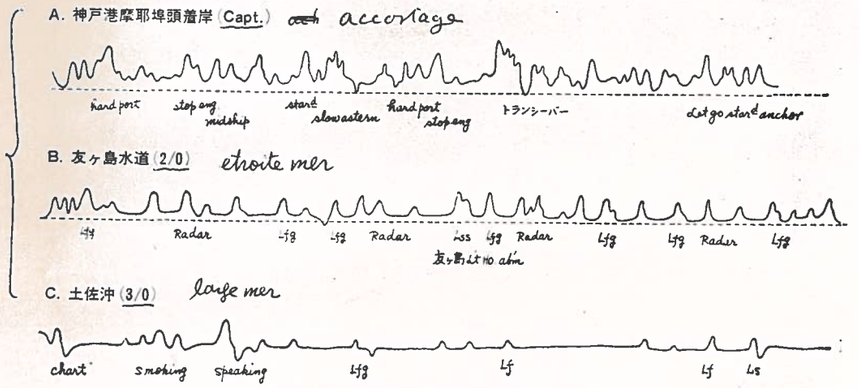


図３　操船作業内容の相違とＰ．Ｇ．Ｒ反応

れの少いことがよくわかる。この二つのパターンをみると同一人の反応かと疑うほどである。

事例3．操船作業内容の相違とP．G．R．反応（図3参照）。

操船作業の内容が異る場面でP．G．R．反応がどうかわるかを比較対照的に示したものである。Aは着岸時の Capt. の反応，Bは狭水道通航時の2/0の反応，Cは open sea における3/0の反応である。これをみるとC→B→Aと反射の頻度が増大することがわかる。着岸は非常な緊張を強いられる作業であることがわかる。この三つのパターンは処理すべき情報量と緊張感との関係を明瞭に示している。事例2の傾向はB．Cの両者にもみられた。

さて以上の三例から若干の一般的考察を行なつてみよう。 P．G．R．は相対強度を示すもので，反射の高さは心的動揺の強さを示すものではない。いいかえれば反射があるということは何か刺戟が存在することを意味する。従つて，我々は反射頻数を手がかりに緊張感の有無を判定しなければならない。厳密にいえばP．G．R．は少しの身体動作にも 反射するから 反射頻数が多い時必ず緊張しているとはいえないが，逆に我々が経験的に知つている緊張場面では反射頻数が多いのである。その意味では三例にみられた反応のパターンはよく経験的事実を実証していると思われる。

3．2．　C．T．G．反応の事例

心搏数もまたP．G．R．と 同様自律神経系の 興奮によつて増す。心搏数は量的把握が可能であり，然も Telemeter の開発によつて 被験者の行動を 妨げることなく測定出来るので，昼夜をとわず実験が可能でこの種の研究にとつて有力な武器である。

事例　4．三原瀬戸通航時の緊張感（図4参照）。

この事例は本研究をはじめるに当つて，C．T．G．測定が 緊張感をどこまで 捉えてくれるか，その可能性を確めるために行なつた最初の実験である〔6〕。同 航の高速小型客船の接近に次第に緊張が高まり，衝突を予想される危機的場面で極度の緊張を示し，C．T．G．が極端に上昇，危

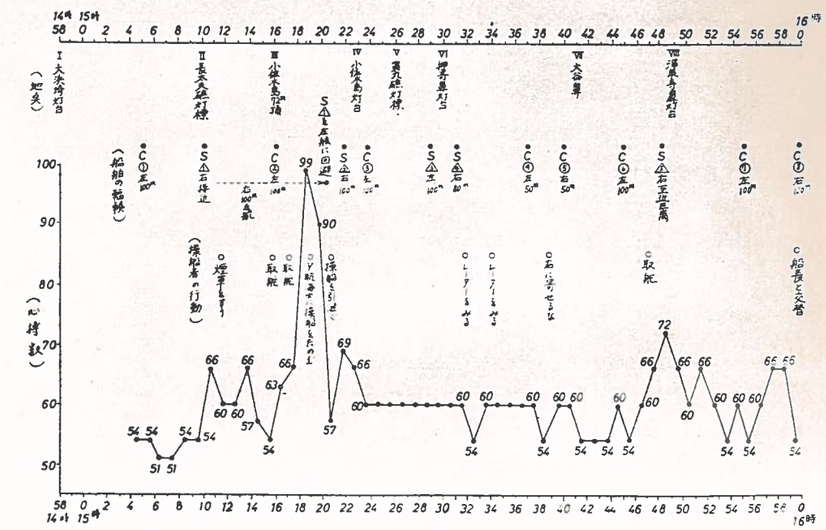


図4　三原瀬戸通航時の緊張感

機が去ると急激に下降している状態がよくあらわれている。

事例5．来島海峡通航時の緊張感（図5参照）。

この実験例は年令57才，海上経歴34年，うち船長経歴15年というベテランの外航船船長が夜航海で来島西水道を通航した時のものである。天候 bc. 南流初期 2 kt. 船長の平静心搏数は80である。記録紙の都合で全通航時間測定出来なかつたのは残念であるが白石灯標並航まで Co 上の反航漁船に敏感に反応し，特に⑤の地点で両側を反航船ではさまれた時のC．T．G．は105の最高値を示す。ここでも事例4にみられた如く相手船の通過し終つたところではC．T．G．は下降している。平均してC．T．G．は95程度である。ところで面白いことには，船長の内省報告によれば「これは好みの問題だが自分は西水道の方が中水道よりも好きだ」「緊張感は全くなかつた」ということである。心搏が105にまで上つたことに対して全く信じられないと首をかしげていたのが印象的である。これは主観的評定と客観的計測にズレのある典型的な例である。

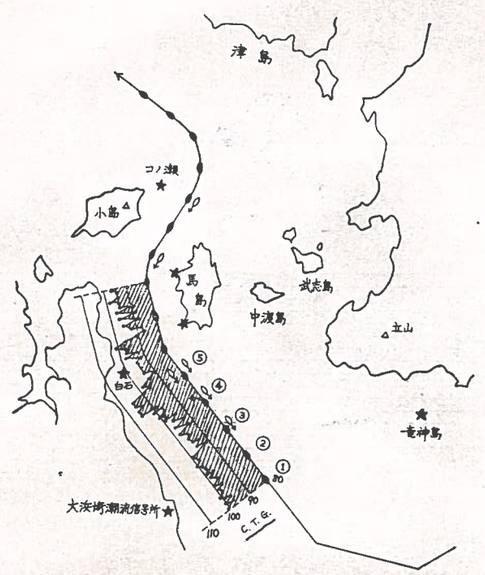


図5　来島海峡通航時の緊張感

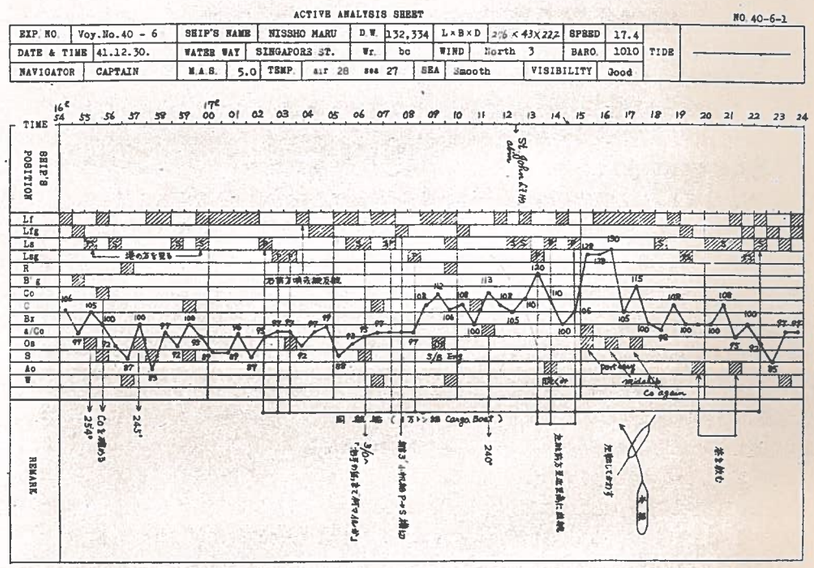
事例6．Singapore St. 通航時の緊張感（図6A・B参照）。

実験船舶はペルシア航路超大型タンカーである。本船は西航の時はバラスト状態で平均吃水8m，トリム4mで Raffles から Nippa をぬけて通航し，東航の時は 満載で吃水 16m の even keel. Philippe channel から Singapore St. に入る。吃水が深いので本船の位置が常に水深20m以上のところにあるよう注意するという。 西航の時は St. John 附近で S/B Eng をかけ Raffles をすぎて Nippa に至る間で R/up Eng とする。また東航の時は Takong 附近で S/B Eng をかけ St. John 附近で R/up Eng とするのが常ということである。 さて船長は海上経歴21年，うち船長経歴5年，42才である。平静心搏数70。

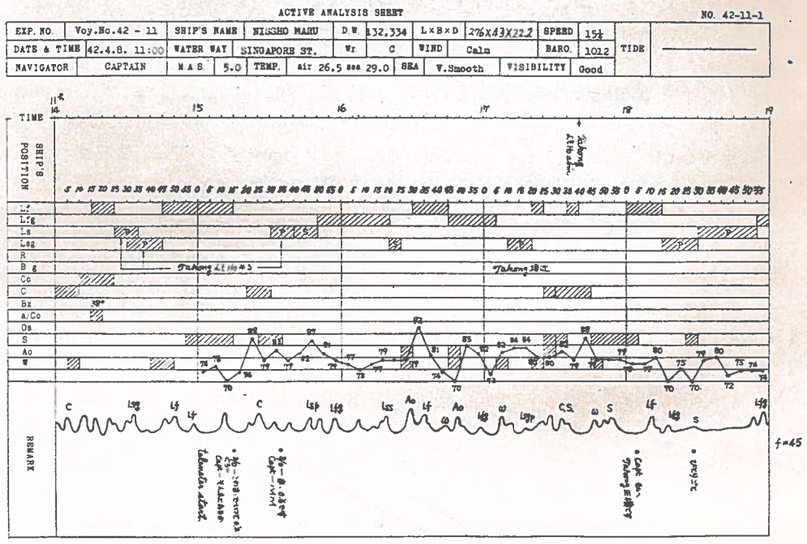
図6Aは西航の例である。動作分析・心搏数を30秒毎に層別サンプリングして構成した活動分析表である。実験開始時既に100前後のC．T．G．がみられるが， これは Singapore 港からの出港船がないかと注意している警戒反応のあらわれであろう。やがて右舷に St. John が接近し，他方左舷に同航船あり，左右に気を配つている様子がよくわかる。特に左舷の同航船に対しては接近するにつれ次第にC．T．G．が上昇，至近距離で両船の Co がクロスしようとする時，一時腕ぐみをして考えたあと取舵で左転しつつ相手船をかわす。この時C．T．G．は130に達した。相手船をかわしたあとC．T．G．は下降，ほつと一息いれて茶をのんでいる。船長の内省報告によれば「St. John の南側を進航中左前方約0.4浬に低速貨物船がいて本船が 右側に 圧せられ浅瀬に接近するおそれがあつたため，本船は思いきつて該船の左側を追越すべく左転したがこの時はかなり緊張した。その他の時は総べて好条件にめぐまれていた」ということで，綜合的にみて今

図6　Singapore 通航時の緊張感

A



B

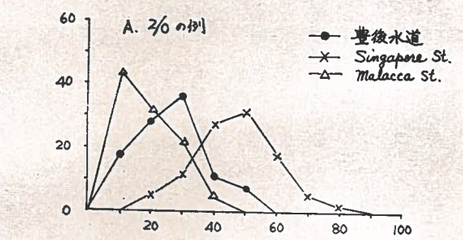


の航海当直は緊張した（評定スケールで緊張度２）という評定を下している。

図６は東航の例。実験記録を最も完全なかたちで示したものである。継時記録のため全実験時間の様子を示すには相当の紙面がいるのでここではその一部５分間のデータを示す。残りのものも殆んど変化がないので，この実験を代表するデータと考えてよい。これをみると P.G.R. は頻繁に反射しているがC.T.G. の方は図６Aにくらべて低い。 Takong の灯台が接近してくる場面であるが附近に船舶もなく，会話を交しながら前方を見張っている様子から緊張は極めて低いことが想像される。果して船長の内省報告は「今日はベスト・コンデイションであつた。全く何ともなかつた」とあり，緊張度の評定は０「何ともなし」であつた。

以上三つの事例を通じていえることは，他船との関係に C.T.G. がよく対応していることである。その意味で緊張感を探る指標としてC.T.G. は最も信用がおけるように思う。ところで，はじめに問題提出した主観的評定とC.T.G. による客観的計測の一致の問題はどうであろうか。来島海峡の例は暫らくおくとして他のケースは皆よく一致していたと考えられる。これを更に別の形で考えてみよう。

図７を参照されたい。試みに一切の条件を無次元化し，心搏数のみをパラメータとして緊張感を考えるとしよう。横軸に平静心搏数よりの上昇率を，縦軸にその頻度をとつてみる。図７AはＩ社N丸 2/0 が異なる三つの水路で示した緊張感，図７Bはさきに事例６で示した同船 Capt. の緊張感である。2/0 の場合緊張感の主観的評定は Singapore St. 東口および豊後水道が緊張度１（少し緊張した）で， Malacca St. は緊張度０（何ともなかつた）である。また Capt. では西航が緊張度２（緊張した），東航が緊張度０（何ともなかつた）である。即ち山が右へ移動するほど緊張感が高くなり，個人差はあるがその人なりにある幅をもつて客観値と主観値とが一致しているように思われる。若し動作分析結果を厳密にチエツクして純粋な精神負荷とみとめられる心搏の瞬時値を抽出して主観的評定との一致をみるならば，或いははつきりしたことが言えるかもしれない。以上は今後 C.T.G. による計測を整理していく上での一試案である。ところで図７Bにみられる如く，同一被験者，同一船舶，同一水路でこのような違いがみられることは緊張感のランダム性を証明するものである。従つて図７Aにおいてあのようなカーブが出たからといつてそれぞれの水路について通航の難易を固定的に順位づける事が出来ないのは言うまでもない。あの時の航海ではこうだつたと言えるにすぎない。



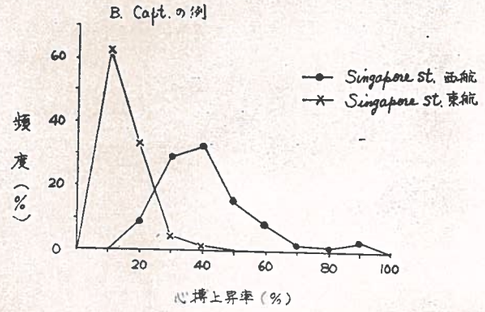


図７　心搏上昇率と頻度

さて，来島海峡の事例で主観的評定では緊張度が０であるにもかかわらず，実際の心搏が多い

のは，あのような典型的な難水路では主観的な評定に対応する心搏のグレードが高いのではあるまいか。この点については，現在継続中の同海峡の実験例がかなりの数になった時更めて考えてみるつもりである。

4. ま と め

航海当直中の操船者の緊張感の動的な実態を人間工学的方法で探ろうとした。果してP.G.R.もC.T.G.も刻々に変動して敏感に反応し生々しい様相を捉えることが出来た。

操船者に加えられる刺戟は陸上の自動車操縦と比べて緩漫であること，刺戟が広範囲に散らばっていることのために，刺戟と反応との関係を一義的に捉えることは困難であるが，概して灯台の接近，変針地点および相手船の存在に対して反応があらわれている。特にC.T.G.は他船の動静に対して判断がつきかねる時，衝突の危険がある対応関係に入った時顕著な上昇を示した。またP.G.R.のパターンでは水路の広狭，未熟練者と熟練者，着岸時と航海時とで明瞭な相違を示した。

実船実験ではその時々の条件に左右されること，アンケート調査ではかくれて出なかった個人差の問題が出てくること等から，数例をもつて全般を論ずることは出来ない。今後は更に縦断的研究と横断的研究とをつみ重ねることによつてこの問題をほり下げてゆきたい。最後に実船実験に御協力をいただいた船長・航海士の各位に心から謝意を表する次第である。

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Ergonomic Research in the Oil Tanker Nissho Maru

研究論文

日章丸における人間工学的研究

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吉川敏枝*，黒田　隆**，松木　哲**

We researched in the accomodations in the Oil Tanker, S.S. Nissho-Maru on the Persian Gulf Line. Results are as follows.

Illumination-levels at night in some rooms are lower than that of Japanese Industrial Standard. We can obtain standard levels of illumination by fluorescent lamps instead of incandescent lamps.

The color design of the accomodations in the ship provides comfortable visual environments.

Noise level in the ship was taken by the sound level meter and the fequency analyzer. On the other hand, sulyective estimations of the noise was given by means of Semantic Differential method and questionaire. As the result of these, it is sugested that below 60 phon (A) in the living rooms, below 80 phon (A) in the work areas may be desirable in the ship.

The atomospheric conditions of the living rooms are rather improved by the air conditioning, but in some work areas such as Engineroom and Galley it is so hot and urgent improvements are expected.

抄　録：船舶の居住環境に関する人間工学的分析の一環として，現在運航中のペルシャ湾航路大型タンカー日章丸に乗船して各種の測定を行なった．結果は次の通りである．

照明：　一般に夜間の人工照明による照度が低く，ＪＩＳの基準に達しないところが多い．これは白熱灯を螢光灯に替えることによって照度をあげることが出来るので改善は容易である．

色彩：　船全体の色彩計画は優秀であって，快適な視覚環境を形成している．

騒音：　船内の騒音を騒音計，周波数分析器等で測定し騒音指数を算出すると共にＳ．Ｄ．法，アンケート等によって騒音に対する主観的評定を行なった結果，騒音計のＡ特性による測定値がＳ．Ｄ．法による尺度値とよく対応することが判明した．本調査の結果から，船舶騒音の許容値として，居室は60ホン(Ａ)以下，作業場では80ホン(Ａ)以下を提案した．

温・湿度：　ペルシャ湾航路における船内は高温であり，特に夏季においてその傾向は著しいが，近年冷房設備が設置されるようになり，温・湿度の条件は公室のみならず，居室においても緩和されるようになった．しかし，作業区では必ずしも快適な作業環境とは云い難い．例えば機関室，調理室等は高温下での作業を余儀なくされている．調理室は高温多湿である．これらの点で改善の余地があると考えられる．

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1.　本研究の主旨

1-1.　研究の目的

最近の海運産業の合理化によって船舶の自動化大型化が急速に進み，そのため種々の心理的な問題が起こって来た．すなわち，

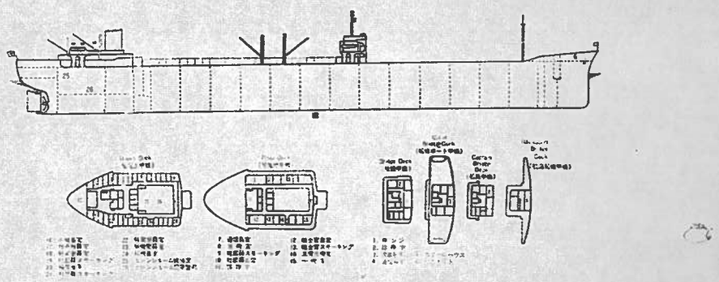


図 1　日章丸の外観図

(1)　機械化が進んだ結果，筋的作業が減少した反面，精神作業が多くなり，精神疲労が増大した．

(2)　運航能率の向上に伴ない，碇泊日数が極端に減少した．そのため乗組員は有給休暇による下船までの期間陸上から隔離された船内生活を送ることを強いられている．

(3)　居住設備は向上したとはいうものの，物理的，精神的居住環境はむしろ低下しているものさえある．例えば振動，騒音が激しいこと，極端な人員削減による疎外感等である．

そこで乗組員の船内生活を快適ならしめ，モラールを高めるためには居住環境は如何にあるべきかを人間工学的方面から究明し，改善策を提案することを目的とする

1-2.　ペルシャ湾航路タンカーに関する調査

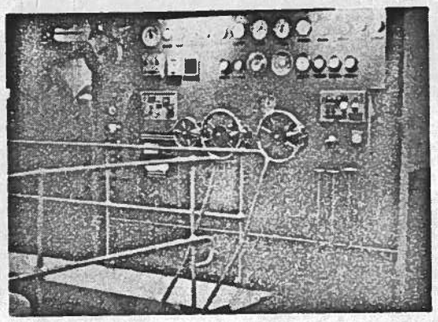
人間工学の立場からみると，船舶については，種々の問題があるが，船舶の種類により，問題になるところも多少相異する．われわれはわが国産業のエネルギー資源として重要な石油の輸送船，ペルシャ湾航路に就航するタンカーについて調査を行なった．

ペルシャ湾航路のタンカーは普通，数万トンから20万トンの大型船であり，速度も大で，操船も漸次自働化の傾向にある．日本からペルシャ湾沿岸の産油地まで往復約35日の航海であるが，熱帯を通過するため，気候の変化が大きい．最近，船内の公室，居室に冷房を実施するようになってから，温度的環境は改善されつつあるが，騒音，振動その他の居住設備では未だ改善すべき数多の問題を蔵している．

タンカーは往復約35日の航海中，目的地以外に寄港しないから，乗組員は殆んど船内で過ごさなければならない．目的地では石油を積載（パイプで船内タンクへ石油を吸入する）する時間と港内の着桟待機時間の合計が目的地での滞在時間であるが普通約1日である．内地碇泊中は石油の陸揚（石油をパイプを通じ陸上のタンクへ導入する）と航海に必要な物資の積込に要する時間が碇泊時間であり，普通約2日間である．内地碇泊中一部の乗組員は休養をとることが出来るが，他の乗組員は作業に繁忙を極める．タンカーの運航状態はいわゆるピストン運転である．したがって乗組員の生活は陸上の産業労働者と著るしく生活形態が異なり，人間生活の上からみて種々の問題を包含する．

調査・測定項目

1. 船内居住区・作業区における照明・色彩に関する調査
2. 船内居住区・作業町における騒音・振動に関する調査
3. 船内居住区・作業区における温度・湿度に関する調査
4. 乗組員の居住・作業環境に関するアンケート調査
5. 乗組員の船内生活全般に関するアンケート調査
6. その他船内環境・船内生活に関する総合調査



（写真）　日章丸の制御室

われわれはタンカー乗組員の居住環境，作業と生活の全般にわたり，調査を行ない，それらの結果に基づいて改善方法を考究したい．すなわち，少しでも乗組員の船内生活を快適にし，これによって志気を高め，運行能率を向上させるとともに，乗組員が悦んで船内の作業と生活をなし得るよう人間工学の立場より改善策を考究せんとするものである．

そこで事例研究による大型タンカー船内居住環境に関する人間工学的分析の一環として，現在運航中のペルシャ湾航路大型タンカーに乗船して各種の測定を行った．対象船（図1参照）および調査項目は表の通りである．

日章丸の性能　船体の長さ：291.00*m*　船体の幅：43.00*m*　深さ：22.20*m*吃水：16.50*m*　載貨重量トン（D/W）：132.33K/T速力：18.11ノット　乗組員：44名

調査時：第40次航海（昭和41年12月24日～昭和42年1月26日）

第42次航海（昭和42年3月11日～昭和42年4月15日）

以上のような調査項目のうち，本稿では照明・色彩・騒音・振動および温・湿度条件について，観測値の分析を行ない，あわせて船内居住環境および作業環境の検討を行なったが，そのうちの一部を報告するものである．

なお，項目(6)の乗組員の船内生活に関するアンケート調査の結果については，機会を改めて分析の予定である

2.　色彩・照明条件の検討

2-1.　照明調査

(1)　調査日時　1967年1月5日～1月12日，午後2時～4時および午後7時～9時

(2)　航海海域　アラビア海，オーマン湾，ペルシャ湾

(3)　天候　晴

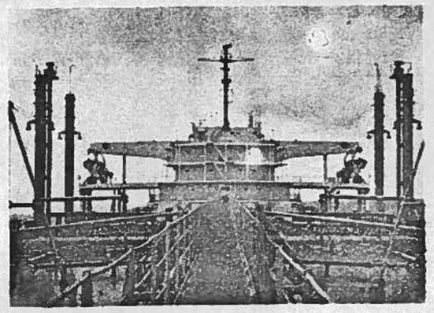
(4)　船内調査箇所　同船内の居住区，制御区，生活区

(5)　使用計器　東芝照度計7号

(6)　調査結果

船室外昼光照度―船室外甲板上の直射昼光照度は5000 lx以上で，東芝照度計7号では測定不能であった．

船室内の照明：昼間および夜間における船内の居住区制御区，生活区の照度を表示すれば表1の通りである．



〔写真〕　日章丸の甲板

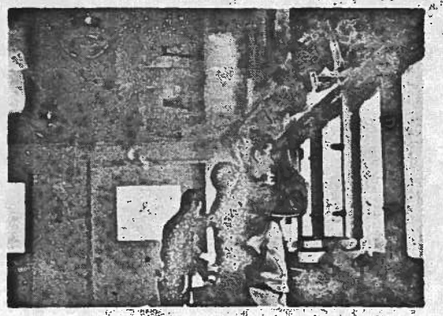
光源：光源は白熱電灯を主体とするが，公室（集会室食堂，喫煙室等）では螢光灯を用いている．

照明器具：照明器具は一般にガラスのグローブのついたものを使用しているが，船員の居住区では乳白色のグローブを，制御区，生活区では無色透明のグローブを使用，また局部照明として机にはスタンドを，錠にはシリンダー型アクリル・カバー付の照明器具，ベッドの側壁には乳白色カバー付ベッドランプを使用している．

照度―昼間は船室の円窓を通して昼光が入射するため概ねＪＩＳの基準照度以上になっているが，夜間は人工照明のみによるため照度低く，基準照度に達しない箇所が多い．昼間，基準照度に達していない船室は船主室，無線室炊事場，浴室，洗濯室等であり，その他は基準以上である．

夜間における室内照明は人工照明のみによるが，基準照度に達しないものが多い．基準照度以上のものは次の諸室である．

集会室，士官室，部員室，部員食堂，部員喫煙室，部員洗面所，海図室，ジャイロ室，これ以外の室の照度は



〔写真〕　日章丸の船橋

表 1　船内主要個所室内照度（単位 iux）

船内測定個所	昼	夜	船内測定個所	昼	夜
居住区			診療室	100	65
ロンジ	200	160	病室	100	80
士官食堂	170	165	通路	10	5
部員食堂	200	130	制御区		
船主室	120	25	操舵室	800	0
船長公室	170(300)	100(140)	海図室	130	0(110)
船長寝室	140	60	無線室	160(180)	30 (40)
サロン士官室	180(280)	60 (60)	ジャイロ室	130	80
士官室	140	60 (85)	生活区		
職長室	100(140)	65 (80)	調理室	30	20
部員室（個室）	50	40	配膳室	30	20
〃（2人室）	40	30	部員洗面所	30	20
士官喫煙室	70	60	便所	30	20
部員喫煙室	100	100	浴室	30	20

（ ）内はスタンドによる局部照明の照度

全て基準に達しない．船内の照度基準は陸上における照度基準より一般に低いが，本調査の結果は船内照度基準にも達しないものが多い．

卓上灯，鏡灯等の照明器具はより効率のよいものと交換すれば，照度は向上する．光源を白熱灯より螢光灯に改め，これに応じた照明器具を使えば簡単に解決される．

ベッドランプは単に睡眠するだけに用いるならば現状でよいが，船員の多くはベッドに横臥しながら読書するので，読書に必要な照度を必要とする．現在は枕元で10～40 lx，なかでも20lx が最も多い．読書には150～300lx（平均 200 lx）必要である．また海図室，無線室等の人工照明は照度を上昇する必要がある．

一般に生活区の照明は貧弱であって夜間照度は極めて低い．白熱灯を螢光灯に切替えるならば，等しい電力で相当高い照度を得ることが出来る．炊事場，配膳室等は衛生上の見地からみて，明視を必要とするので照明をよくしなければならない．

(7)　照明調査結果の要約　一般に夜間の人工照明の照度が低い．これは白熱灯を螢光灯に替えることによって照度を上げることが出来るので，改善は容易である．

2-2.　色彩調査

(1)　調査日時　1967年1月16日午後2時～4時

(2)　航海海域　アラビア海

(3)　天候　晴

(4)　船内調査個所　同船内の居住区，制御区，生活区

(5)　調査方法　日本色彩社，産業用標準色票（マンセル方式）により色合わせを行ない，調査した．

(6)　調査結果　いま居住区，制御区，生活区について，色彩を調査した結果は次の通りである．

居住区の天井は全部白（9.3N）である．壁は公室および船主室，船長室機関長室ではYR系，士官室部員室，診療室等ではYG（7.5YG9/2）を使用している．床はR(2.5R3/5)，扉はBG(10BG6/1)，家具もBG（10BG6/1）である．机は灰色（7Nまたは8N）である．

通路の天井および壁は彩度の低いY（5Y9/2），床はR（2.5R3/4），扉はBG（10BG6/1）である．

制御区の天井は操舵室(7.5G9/1)以外は白(9.3N)壁はG(7.3G9/1)，巾木はBG（10BG6/1），床は操舵室がG（2.5G6/2），無線室はBG(7.5BG5/2)，海図室，ジャイロ室等はR（2.5R3/5），扉，家具はBG（10BG6/1）を使用している．

生活区の天井および壁は白（9.3N），巾木は炊事室，配膳室（10BG6/1）以外洗面所，便所，浴室，洗濯室等で黒（1.5N）を使用し，床には白（8.5N），扉にはBG（10BG6/1）を使用している．

制御区で使用せられる航海計器類，無線機械類はG系統（2.5G7/2）である．

炊事室，配膳室等の各種の器具・什器には白（9.3N）が多く用いられている．

(7)　色彩調査結果の要約　色彩計画は船内のみならず船の外装部すなわち，船体の色彩計画全体が優れていると思う．快適な視覚環境を形成していると考える．

3.　騒音条件の検討

3-1.　測定目的

船舶の騒音の乗組員に与える影響は心身共に無視できないものがあり，従来も各種の研究が行なわれている．これらの研究は主として船舶騒音を物理的に詳細に測定し，測定結果より聴覚の特性と対応した種々の指数，たとえば SIL, NC, NCA, NC-dB, NRN などを算出し，これについて許容値その他の考察を行なったものが多い（中野，1965；神田，1964）．一方，物理測定は行なわず，アンケート調査によって乗組員の騒音はじめ船舶環境に対する意見（主として苦情）を求めたものもある．

われわれの騒音の測定は，一方では騒音を物理的に組織的かつ出来る限り精密にとらえると同時に，他方では Semantic Differential や意見調査など，乗組員に主観的評定を求め，物理量と心理量との対応関係を求める．

この結果から船舶の許容値に対する一つの提案を行なうと共に主観量と対応のよい船舶騒音の物理量測定方法の指数の算出について考察を行ない，さらに船舶騒音の主観的測定法についても提案を試みたい．このような目的のもとに一連の測定を行なった．

3-2.　物理的測定

(1)　測定対象船：出光タンカー日章丸

(2)　測定器：騒音計　リオンNA-02型2台，リオンNA—07A型1台，周波数分析器　リオンSA-55型，テープレコーダ　ソニー7772J型

(3)　測定項目および方法：i) 船内全居室に対し，A特性を用いて25回測定．ii) 船内主要26カ所を，C，B，A 3特性について，5秒間隔25回測定．なお，この data は，Semantic Differential による主観量と対応づける iii) 後部居室8カ所について，C，B，Aの3特性およびオクターブフィルターの9帯域全部について5秒間隔で各50回づつ測定．また，同時に騒音のステレオ録音を行なう．この録音を用いて後に実験室的研究を行ない，船舶騒音の大きさおよび喧騒度の正確な結果を求める予定である．また iii) の data は ii) の簡易な測定結果の信頼性の確認および，将来，聴覚と対応づける実験の基礎資料として用いる予定である．

3-3.　主観的測定

1.　船内騒音の音色評定

(1)　目的：複数の評定者によって船内各箇所をSemantic Differential（S.D.法）を用いて主観評定し，物理測定の結果と対応づける．評定者は船内各箇所の騒音について，評定用紙を用いて評定を行なう．評定尺度は北村，難波ら（1963）の資料を参照して選択した．

(2)　方法：i) 評定者(11名）はなるべく全乗組員を代表しうるように甲板・機関・事務の各職務別，前部および後部居住区別，職員・傭員別に考慮して各層より選択した．評定場所は予備調査により26箇所を設定，職場および居住区を含み，レベルの低いところから極めて高い場所まで含めてある．評定用紙記入の要領並びに注意事項を，評定用紙と共に各評定者に配布し，各評定場所に案内して評定を行なった．評定は往航時，帰航時に各一回実施．

(3)　評定日：往航時—昭和42年3月19日　帰航時—昭和42年4月9日

(4)　結果と考察　結果の一例(往航時)を図2に示す．往航，帰航時の評定結果を通覧して次の傾向が伺われた．

A特性による測定値が，50～52ホンであれば，大体静

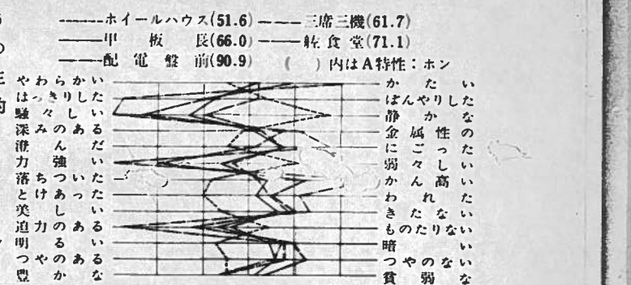


図 2　船内騒音の音色評定

かな環境と感じられ，55ホン前後であれば，まず可もなし不可もなしといった状態で，生活する上に全く支障がないといってよさそうである（NRN44～60）．60～64ホン(A)になると，“騒々しく”感じられ始め，65ホン(A)を越えると，“騒々しい”“力強い”“迫力”の尺度値が高くなると共に“にごった”“きたない”等，音色の悪化がみられる（NRN58～64）．さらに，70ホン(A)を越えると，“騒々しさ”“力強さ”“迫力”の尺度値が更に高くなり，“きたない”“にごった”等，音色が悪くなると共に，“はっきりした”“かたい”“かん高い”“金属性”の不快な音色となる（NRN64～69）．80ホンを越えると不快感は極度に高くなり，生活に不適当であることはいうまでもない．このレベル付近になると聴力損失の心配がでてくる（NRN81～87）．なお，各測定点毎に往航時の評定と帰航時の評定を比較すると，やはりレベルが高いのを反映してか，帰航時の評定の方が，悪い評定を得ている．

2.　騒音・振動に関する意見調査

(1)　目的：上記の音色評定は，各評定点における騒音の感じを瞬間的にとらえたものであって，そこで長時間，生活し作業している場合の資料ではない．従って，この騒音下で暮している人々にとって，その騒音が日常生活の上にどのような影響を与えているのかを求めているものではない．そこで，騒音ならびに振動の船内居住生活におよぼす影響を知る目的で，各自の居室について以下のアンケートを行ない，物理的測定の結果およびS.D.法による騒音評価と対応づけて考察する．今回の報告は主として騒音を中心に分析する．振動に関しては，第2報にゆずりたい．

(2)　方法：全乗組員に調査用紙を配布し，留置式で記入を求めた．

(3)　調査日：昭和42年4月10日配布，同月13日回収

(4)　結果と考察：問1　この設問は43の質問文より構

成されている．その内容を分類すると，乗組員の居室騒音に対する綜合的評価，乗組員が船のどのような種類の騒音をうるさく感じているのか，騒音に対する慣れ，態度，騒音と身体条件との関係，騒音と睡眠の関係，たとえ何らかの代償を払っても居室を代りたいと思っているかどうか，騒音と読書・考え事・会話との関係などの問題について卒直な意見を求めたものである．

単純集計の結果は明瞭な傾向が得られなかったが，騒音レベル別層別分析した結果，大要つぎの傾向が得られた．すなわち59ホン(A)以下では居室として問題はない．一方70ホン(A)を越えると，これは居室として，精神的にも身体的にも問題があるのではないかと思われる．従って60～69ホン(A)の間が許容領域ということになるがS.D.法の結果などからみて，やはり少くとも65ホン(A)以下に押えることが望ましいのではないかと思われる．

問2　この設問は，他者（第三者）の騒音・振動に対する苦情を尋ねるという形式をとっている．この形式をとることによって，自己の不満としては表現し難いことも知ることができる．

さて，眠れないといった苦情が上位を占め，レベル別に分析しても，項目1（騒音がうるさいのでよく眠れない）の場合には，レベルが上がるにつれて反応数も増加し，70ホン(A)を越えると全員（100%）が肯定している．同様に項目7（騒音がうるさいので部屋を代りたい）についても，レベルが上がるにつれて反応数が増加し，やはり70ホン(A)以上では100%が肯定している．50ホン(A)以下では非常に少ない（14.3%）．このように問2の結果は問1のそれを裏書きしているようである．

問3　この設問は，改善を希望する環境条件を尋ねたものである．

騒音レベルが50(A)以下であると，振動や騒音の軽減よりも，むしろ冷暖房の調節や照明の改善が要求されている．60～64ホン(A)では，騒音・振動の改善が2，3位に上がっているが，しかし照明の改善が第1にあげられている．ところが，65ホン(A)以上になると，振動・騒音が1，2位を占めている．

この結果よりみても，やはり59ホン(A)以下では問題はなく，60～64ホン(A)程度から騒音の影響が出始め，65ホン(A)以上では生活の妨げになっていることが推察できる．

表2　騒音各指数と音色評定と相関係数

	A	B	C	NRN	SIL
A	——	·952	·882	·952	·971
B	·952	——	·975	·921	·962
C	·882	·975	——	·839	·923
NRN	·952	·921	·839	——	·901
SIL	·971	·962	·923	·901	——
かたい——やわらかい	·955	·954	·909	·900	·950
にごった——澄んだ	·922	·904	·846	·847	·920
かん高い——落ちついた	·916	·867	·802	·832	·901
力強い——弱々しい	·930	·912	·957	·850	·936
迫力のある——もの足りない	·927	·876	·824	·856	·915
騒々しい——静かな	·904	·894	·848	·841	·909
はっきりした——ぼんやりした	·856	·763	·655	·811	·813
暗い——明るい	·736	·765	·752	·641	·769
金属性の——深みのある	·578	·542	·532	·507	·573
きたない——美しい	·809	·813	·789	·721	·855
つやのない——つやのある	·669	·732	·725	·592	·693
われた——とけあった	·720	·678	·624	·627	·737
豊かな——貧弱な	·172	·020	·042	·169	·083

表中のS.Dの形容詞尺度は相関係数が正の値になるよう形容詞対の位置を変更してある．

3-4.　物理量から算出した種々の評価数（NRN, SIL, sone, phon）とS.D.法との関連

以上の主観的測定の結果と物理量とを対応づけて，船舶騒音に適切な評価数の選定を行なうことができる．

さて，騒音の物理的測定はすでに3-2で述べたように騒音計のC，B，A3特性で測定すると共に，オクターブ・フィルターによる周波数分析を行なった．この周波数分析の結果より，NRN, NC. SIL等の騒音の評価値および sone, phon 等の騒音の大きさを算出した．なお，ここで，A，B，C各特性および NRN, SIL, sone, phon 等の数値は，物理量から感覚量を推定するべく求められたものではあるが，感覚量そのものではない．そこでこれらの数値の総称として，仮に騒音各指数と呼ぶことにする．

これら騒音各指数間の相互相関係数（表2）をみると，全体に高いことが分る．このことは，いずれの指数も同じものを指示していることを示唆している．換言すれば1つの指数のみで，他の指数を代表しうる可能性のあることを意味する．これらの指数の中で，特にA特性による測定値が他の指数との相関が高い．表からも明らかなように，騒音各指数とS.D.法の尺度値の間にも高い相関関係のあることが分る．特にA特性とS.D.法の尺度値の間の相関が高い．これらの結果は，A特性の測定値をもって，他の指数の代表としうることを示唆している．

S.D.法の尺度値の中で，騒音各指数との相関の高いのは，“かたい—やわらかい”，“にごった—澄んだ”，“かん高い—落ち着いた”，“力強い—弱々しい”，“迫力のある—もの足りない”，“騒々しい—静かな”などで，“豊かな—貧弱な”は，相関係数が目立って低い．

次に，S.D.法の尺度値とA特性の関係について，散布図を作って考察してみると，散布が尺度値1付近から7付近に及ぶものと散布の範囲が狭いもの，散布が4付近に固まるもののあることが分った．もちろん，散布が1から7に及び，かつ相関係数の高い尺度が，騒音の物理的変化を敏感にとらえうる尺度ということができよう．このような観点よりみて，特に“やわらかい—かたい”“騒々しい—静かな”の両尺度は騒音の評定に適当な尺度ではないかと思われる．

結論として，騒音の物理的測定は騒音計のA特性を用い，S.D.法による評定は“やわらかい—かたい”“騒々しい—静かな”の2本の尺度だけでよいということになる．もちろん，この結論は日章丸と類似したタイプの船舶騒音に限ることを断っておかねばならない．

3-5.　船舶騒音の許容値

現在までに得た資料のみで船舶騒音の許容値を決定することは，もちろん無謀である．しかし，得た資料の範囲内で一つのケースとして許容値について考えてみよう．この際に参考になるものが，騒音各指数について求められている既存の基準値であるが，これを船舶の居室に適用した場合，この基準は船舶にとっては低すぎるようである．（例，住宅はA特性で40ホン，寝室はNCで30，NRN30というように低く，本船の場合，この基準を下廻る居室はない）

そこで，S.D.法およびアンケートの結果より推定してみて，居室は60ホン(A)以下であればまず良好，65ホン(A)までは何とか許容できる．65ホン(A)を越えると不快感を与え易く，70ホン(A)以上は不適当といえよう．公室の場合は，SILが50以下であれば，6ft離れて普通の声で会話できるので，まず問題はないといえよう（本船では，SIL 50以下の時，騒音レベル67～68ホン程度であるので，喧騒度の面からいっても，公室であれば我慢できるであろう）．作業場も，喧騒度および会話の面からいって，70ホン(A)以下に押えたいところであるが，本船のような周波数特性の騒音の場合，聴力保護の点から考えて，上限は80ホン(A)以下にすべきであろう．

4.　温湿度条件の検討

ペルシャ湾航路は，我国の温帯地域から，南支那海，マラッカ海峡，インド洋の熱帯の水域を経てペルシャ湾の亜熱帯乾燥地帯に航海するものであるため，気候の激変が著るしく，航海中，乗組員の中には身体の不調を訴える者が多く，久保の研究によれば，持続的な高温の作用によって水血症を来たしたり，血圧低下，体比重低下が見られることが明きらかにされている．その他，高温のための体重減少，倦怠感，頭痛感の訴えはよくなされるところであり，こうした事情を反映して国際労働条約に基づく設備の改善が行なわれる一方，ペルシャ湾航路のタンカーには冷房設備が義務づけられたり，高温下での作業規制が行なわれたりしている．しかしながら，これらの冷房設備は船内の居住区，作業区のみであって，甲板作業は炎天下で行なわざるを得ない時もあるし，機関室，調理室等は高温から逃れることはできない．

そこで，次に環境条件の検討の一環として，温熱条件をとりあげ，分析するものである．

4-1.　方　法

船内主要個所において，温度，湿度の定時測定を行ない，更に乗組員全員にアンケート用紙を配布し，居室，作業区の温湿度条件について回答を求めた．

(1)　温湿度測定器具　アースマン通風式温湿度計，乾湿球温度計，最高最低温度計，毛髪式湿度計等．

(2)　測定場所　表3に示す8カ所の他船内主要18カ所

(3)　測定日時　日章丸第42次航（昭和42年3月11日～4月15日），定時測定時刻，午前10時（9.30～10.30）

4-2.　結果および考察

各測定場所にける観測値から，1航海約35日間の平均値および標準偏差値を算出したものが表3である．対象船はミドルブリッヂ方式のタンカーであり，居住区は前部と後部に分かれている．後部エンジンハウスは，エンジンという熱源のため，全般に温度が高くなっており，居室で平均25°C前後，通路で30°C前後となっている．しかし，これは定時測定の温度であって，最高温度の平均値となると，1標準偏差分の値で，居室で23°C，通路で37°Cをこえ，外気温の最高温度が31°Cであるから後部ハウスは非常に高温といえる．これに反し，前部ブリッヂハウスでは，総じて温度は低く航海中の経験ではロンジ等はむしろ寒く感じられる時もあった．比較的高温の後部居室といえども冷房設備が設置されることにより条件は緩和されている．

図3は航海中の温度の変化を，戸外と，居室，作業区の一例として各々，甲板長室，のである．外気温は出港

表3　船内主要個所温湿度平均値

測定場所	最高温度 °C 平均	最高温度 °C SD	最低湿度 °C 平均	最低湿度 °C SD	温度(10時) °C 平均	温度(10時) °C SD	湿度(10時) % 平均	湿度(10時) % SD
戸外	27.8	3.2	23.2	4.4	25.0	4.1	72.2	14.6
ロンジ（前部）	23.4	2.4	20.1	2.3	22.0	2.[illegible]	58.7	10.6
航海練習生室(前部)	27.8	1.3	24.2	1.8	24.7	2.0	53.7	8.7
通路−3(後部,左舷)	35.2	1.9	29.7	2.3	29.0	3.3	49.1	10.8
三等機関士室(後部)	27.0	2.4	26.6	2.3	24.8	3.1	52.1	11.4
調理室（後部）	38.5	3.3	27.9	3.4	29.8	3.4	60.2	12.9
甲板長室（後部）	29.3	2.6	24.2	2.6	26.9	3.0	47.7	10.8
機関室（後部）	36.1	3.2	33.8	5.2	33.1	3.9	47.9	13.3

後数日にして急上昇し，25°～31°Cとなり，ペルシャ湾に入る頃から又降下する．そして，こうした温度変化を往航帰航と2度繰り返すことになる．居室は熱帯水域航海中，すなわち，東支那海からアラビア海までの約10日間は，船内に冷房の空気調節が行われるため，26°C前後を保っている．日本近海，ペルシャ湾航行時は冷房が行なわれないため室内温度はやや高めとなるが，通風換気は常時行なわれており，結局，居室に限ると，温度条件は快適とまでは行かなくとも，暑さに悩まされることはない．仮に暑い時があっも冷房ダクトの方向を変え調節することにより，暑さは容易にしのぎ得るといえよう．

しかしながら問題はむしろ作業区に残されているのであって，表3に目立つことは高温作業場として調理室と機関室があげられることである．前者では平均30°C，最高38°C，後者では平均33°C，最高温度の平均値36°C，1標準偏差内の最高温度では 39°Cを指すにいたり，各個観測値では 41°Cに達する時もあった．こうした環境での作業は重労働であり，アンケート調査でも機関室では

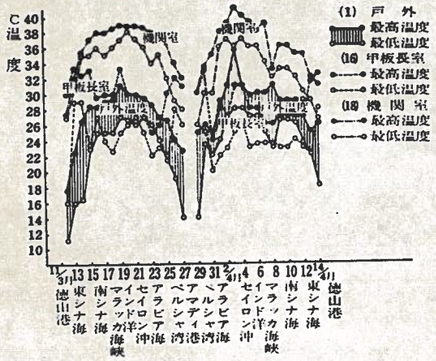


図3　気温の変化

少し暑いと感ずる者10名，非常に暑いと感ずる者4名で計93%にも及ぶ者が暑さを訴えている．調理室でも事情は同様であって，7名中6名までが非常に暑いと答えている．従ってこれらの部署での作業には設備として更に強力な冷房装置が必要とされよう．神田によれば85%以上の人が快適と感ずる感覚温度は，冬 18.3～21.1°C，夏20.5～22.8°Cであり，各種作業の至適温度は13～18°C，筋的作業で 10.0～17°Cであるのを見れば船内のこれらの作業区は非常に高温と言わねばならない．そして，湿度に関しても，表3のごとく全般には50%前後に分布しているが，その主観的評価では，機関室，調理室においてのみじめじめしているという反応が出現しこれらの2作業区は温湿度両面から至適条件とは言い難いものとなっている．

機関室では計器盤，操作盤前は空気調節され，冷気が吹きつけられているが，その近傍においてすら図3のごとく熱帯水域通過時は 35°C を越えており，計器盤，操作盤前を離れると更に高温となろう．

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to Prof A. Wisner
With best wishes,
Sadao Horino

ENVIRONMENT ASSESSMENT AND CONTROL IN FOUNDRIES IN RELATION TO WORK LOAD

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Introduction

Like in other manufacturing industries, the workshop environment in foundries involves many hazardous factors. In spite of technical progress that has taken place in foudries, the main safety and health problems remain just as before. Occupational injuries and diseases of the foundry workers are relevant to their workshop environment and general working conditions, such as hours of work, and the problems involved in both these factors had not been solved by exsisting installations which were partially 'automated.'

It has become less attractive for the younger generations these days to have jobs in foundry workshops. This tendency is clearly indicated in the recently surveyed labour force composition in foundries. The average age of the workers was 44.1 years, and more than 64% of the total 259 workers in three establishments combined were over 40 years old. Teen-age workers were very few, and those in their twenties were only 15%. Such distorted age composition is undoubtedly due to the dirty, hot or cold, poorly-ventilated, inadequately-lighted, and dangerous environment in foundry workshops.

This paper intends to assess the environmental conditions in foundries in relation to work load, comparing the results between automated line processing and manual workshops, and then to suggest some engineering recommendations for effective environmental control in foundries.

Method

The field survey was carried out in four fondry firms. They produced parts for diesel engines, parts for hydraulic devices for construction machinery, parts for food processing equipments or home-appliances. The number of workers in each firm varied from about 30 to 130.

Physical measurements in atmospheric conditions, illumination, noise, and air-borne dust concentrations were conducted at almost all the major workshops. Among them, two automated line processing workshops and nine manual workshops were chosen for further study.

For these two types of work, various tools were applied. An ergonomics check list was used by 9–10 ergonomics specialists. Subjective feelings of general fatigue were recorded for several days for each worker before and after a day's work. And, subjective evaluation of environments using 50 pairs of adjectives were also recorded for each worker, simultaneously with physical measurements. Time study was conducted to study frequency of various working postures.

Results

Through the physical measurements and as-

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Table 1. Noise and air borne dust concentrations in various foundry workshops.

Workshops		Noise dB (A)	Air borne dust concentration mg/m³
Line process	Moulding and pouring	73 –112+	6.7 – 8.6*
	M. and P. core setting	82 – 105+	2.2 – 13.5*
Mechanized moulding		77 – 105+	5.0*
Manual moulding		70 – 97+	3.8 – 17.5*
		72 – 97+	2.5 – 10.5*
		75 – 88	2.2 – 17.5*
Core making	Work at the table	72 – 90+	5.0* – 9.7*
	Shell moulding	72 – 88+	3.8 – 6.0*
Sand mixing		83 – 94+	3.1 – 9.9*
Finishing	Grinder	78 – 99+	38.9*
	Pneumatic chipper	104+	133.0* – 217.0*
	Pneumatic chipper	92+ – 118+	3.6 – 17.5*
	Hand grinder	95+ – 118+	389.5* – 479.1*
Melting furnace		66 – 119+	1.3 – 28.7*
Core knock out		77 – 108+	3.7 – 17.5*
Over head crane operator cabin		75 – 95+	4.7 – 6.0*
Office		50 – 69	1.0 – 4.7

+: over 90 dB (A), *: over 5 mg/m³

sessments of the working environments in various workshops, it was found commonly, regardless of the size of the enterprise and their products, that exposure to the remarkable dust concentrations and high noise levels were primarily observed in almost all the workers surveyed as shown in Table 1. The general dust concentrations varied between 3 and 38 mg/m^3, in some finishing processes the highest measurement reaching the 300–400 mg/m^3 level.

Exposure to noise was significant due to accelerated mechanization. General noise levels for the foundry workshops varied between 70 and 100 dB(A), and various pneumatic devices caused noise levels reaching above 90–110 dB(A), some times being close to 120 dB(A). Frequency analysis for some moulding machines and devices indicated that their sound included higher frequency components harmful to the worker's hearing.

Illumination was another factor which needed active improvement. Many workshops had illumination levels of under 100 lx. It was also observed universally that the air-borne dust accounted for poor and inefficient lighting.

There were no systematic ventilation and air-conditioned system in the workshops, though the plant building structures had high ceilings and wide and open doors. Therefore, the temperatures were very close to those of the outdoors, namely it was very cold during the winter and very hot in summer.

Table 2. Frequency of items checked by more than half of the checkers from ergonomic points of view in the manual moulding work and the line process moulding work.

Chapter	Number of items	Manual work	Line process work
1. Work space	22	50.5%	90.9%
2. Seat and foot rest	26	7.7	42.3
3. Controls	56	14.3	28.6
4. Information displays	36	5.6	25.0
5. Combination of displays and controls	37	2.7	35.1
6. Working environment	50	52.0	68.0
7. Posture and static work load	39	48.7	46.2
8. Dynamic work load	35	82.9	74.3
9. Hours of work and work performance	33	45.5	45.5
Total	334	33.5	48.5

(Note: checkers were 9–10 ergonomists.)

An ergonomics checklist consisting of nine chapters and 334 items was used to evaluate those two kinds of workshops (automated line processing work and manual moulding work). A check item which was checked by more than half of the checkers was regarded as indicative of necessity for taking ergonomic countermeasures. Frequency of items checked by more than half of the checkers in each chapter in percentage of the total number of check items was calculated for each chapter and shown in Table 2.

The frequency of checked items was higher than 50% for the chapters 1, 6, and 8; namely for workspace, environment and dynamic workload. The frequency of checked items was higher than that for the manual work as to all chapters from 1 to 6 including working space arrangement and workshop environment. Only in chapters 7 and 8, which referred to posture and static and dynamic work load, the frequency for the manual work was higher than that for the automated line processing work.

This implies that the automated line moulding systems which are contributing to a higher productivity in comparison with the manual work do not necessarily provide good workplaces from ergonomic viewpoints.

According to the analysis of subjective ratings of the environment by means of the Semantic Differential method, profile of evaluations of the workers was different between two types of workshops. The typical profile is shown in Fig. 1.

Workers who were doing their jobs on the automated line processing felt much more dusty and noisy, and felt workspaces narrower than people of other shops did. And the workers on the automated lines also evaluated their environment as rather confined, tiresome, boring, heavy, hard and irritating.

It should also be noted that the workers producing much noise felt relatively noiseless than the workers who were making less noise in their work and were affected from outside noise. It was common to almost all the workshops studied that noise and dust of some working places such as moulding machines and frame breaking machines affected all the other workers in the same building.

Figure 2 shows the relative frequency of various postures in automated line paced work and unpaced manual work. Paced work included more standing postures and fixed postures than the manual work did. And manual moulding job included in high frequency unnatural postures such as forward bending with maximum efforts. Even in automated line jobs, high frequency of deep foreward bending either with or without maximum efforts was observed due to poor design of the workspace and material handling equipments.

Figure 3 shows a fixed standing posture in automated line processing work. The workers are engaged in setting cores in frames repetitively. Figure 4 shows a deep bending posture which is seen generally among manual moulding work. The worker is assembling an upper frame with a lower frame with deep forward bending with the maximum efforts. And Fig. 5 shows another deep forward bending posture in manual moulding. Figure 6 shows that the worker is obliged to push heavy frames by hands with deep forward bending posture due to poor designing of the material handling equipment of the automated line processing.

Table 3 shows the average rates of subjec-

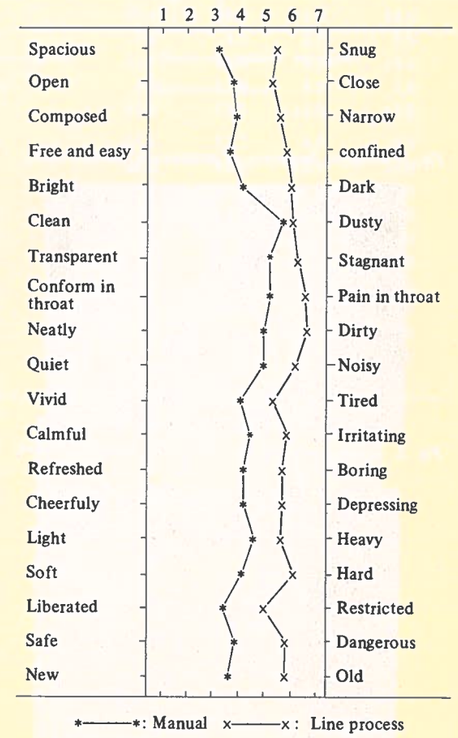

Fig. 1. Profile of the feelings and subjective evaluation for environment in the manual workers and the line process workers.

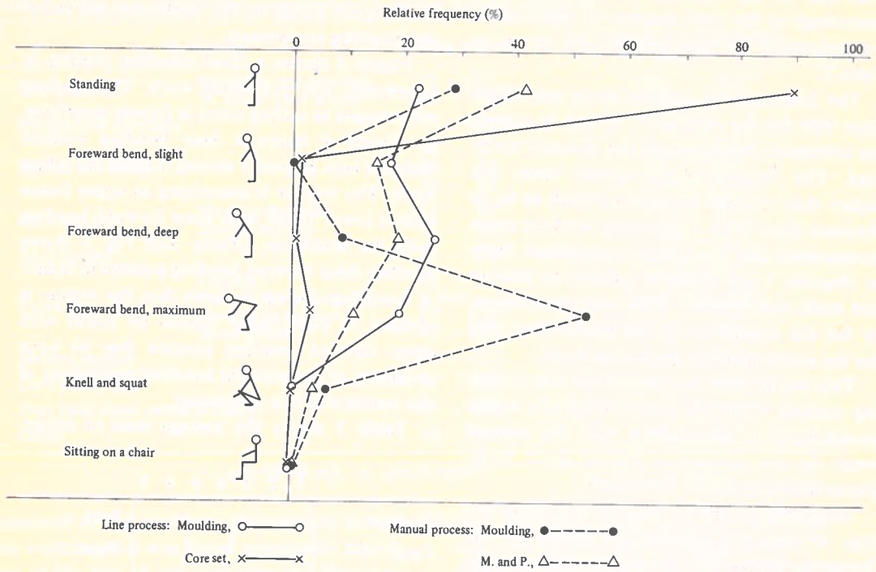

Fig. 2. Relative frequency of postures in foundry work.

Fig. 3. A fixed standing posture in automated line work.

Fig. 4. A deep bending posture in manual moulding work.

tive feelings of fatigue before and after work for manual workers and automated line workers. The 30 items listed are those proposed by the Industrial Fatigue Research Committee of the Japan Association of Industrial Health.

The mean frequency of complaints of fatigue after work was 16.1% for the manual workers, higher than that of the automated workers of 13.6%. The manual workers complained more of most items of the second component indicating difficulty in concentration, as well as stiff shoulder and low back pain. And on the other hand, the frequency of the complaints was higher for the automated line workers with respect to tiredness in the legs, yawning and drowsiness. It can be regarded that these differences between two groups resulted from difference in the major working postures as well as difference in type of work.

Discussion

We have seen that poor environment and inappropriate work space arrangement clealy present problems also relating to work load.

Table 3. Mean rates of subjective feeling of fatigue for the manual moulding workers and the line process moulding workers before and after work.

Category	Item	Manual workers		Line process workers	
		before	after	before	after
I	Feel heavy in the head	16.3%	14.3%	8.0%	8.0%
(Dull-drowsy factor)	Feel tired in the whole body	15.4	15.9	8.0	16.0
	Feel tired in the legs	21.1	34.9	26.0	56.0
	Yawning	13.0	4.0	24.0	20.0
	Feel hot headed or muddled	16.3	11.1	10.0	14.0
	Become drowsy	23.6	8.7	8.0	14.0
	Feel eye strain	23.6	41.3	16.0	42.0
	Become rigid or clumsy in movement	11.4	12.7	10.0	6.0
	Feel unsteady while standing	11.4	9.5	4.0	6.0
	Want to lie down	13.8	19.0	6.0	14.0
II	Feel difficulty in thinking	8.9	9.5	2.0	4.0
(Factor of difficulty	Become weary of talking	6.5	4.8	4.0	2.0
in concentration)	Become nervous	10.6	17.5	6.0	8.0
	Unable to concentrate	11.4	11.9	6.0	6.0
	Unable to show interest in things	11.4	7.9	4.0	4.0
	Become foregtful	15.4	16.7	8.0	14.0
	Lack of self-confidence	5.7	4.0	0.0	0.0
	Anxious about things	17.1	18.3	8.0	18.0
	Unable to straighten up oosture	9.8	11.9	4.0	2.0
	Lack patience	13.8	13.5	12.0	12.0
III	Have a headache	14.6	12.7	4.0	8.0
(Factor of physical	Feel stiff in the shoulders	26.8	42.9	20.0	26.0
disintegration)	Feel pain in the low back	26.8	46.0	28.0	36.0
	Feel constrained in breathing	8.1	11.1	8.0	8.0
	Feel thirsty	14.6	37.3	22.0	34.0
	Have a husky voice	19.5	19.0	6.0	8.0
	Experience dizziness	6.5	3.2	4.0	4.0
	Have eyelid spasm	3.3	5.6	12.0	8.0
	Have tremor in the limbs	2.4	7.1	0.0	0.0
	Feel ill	7.3	9.5	2.0	10.0
	Number of cases	123	126	50	50

Fig. 5. A deep forward bending posture in manual moulding work.

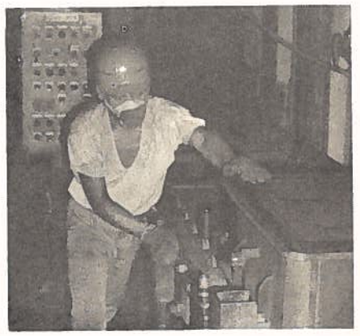

Fig. 6. Pushing a heavy frame by hands with deep forward bending posture in automated line processing work.

And even in automated line processing, poorly designed work space resulted in very high proportion of unnatural working postures and intensified work load, which was specifically combined with constant exposure to dust, noise and climatic stress.

As engineering countermeasures for these ergonomic problems, I suggested re-arrangement of workshops layout and the flow of processing in the plant so that hazardous environment may not affect other neighboring workshops. Pouring and core knocking workshops should be arranged at a fixed area installed with effective dust and noise control equipments. Secondly, the overhead cranes should be taken away from the workshops and be replaced by ground level material handling devices or equipments, so that re-arrangement of workplaces may become easier. And thirdly, a new type of the work bench for manual moulding which is adjustable in the height and inclination, is being developed to make working postures more natural and easy. Finally, better workspace arrangement and machines with less noise and dust should be taken into consideration in the automated lines.

A common misunderstanding about ergonomics solution of human problems in the workshops is that they must involve a high degree of mechanization, automation or some form of replacement of men by machines. From the working conditions viewpoint, appropriate design of a job should primarily involve reduction of environmental hazards and excessive work demands, and to realize this, more practical means are needed, which do not necessarily include higher automation.

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To Prof. A. Wisner
with best wishes,
Sadao Horino

Work performance assessment of intercity truck drivers in relation to workload

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A field study conducted for assessing the intercity truck drivers' work performance revealed that driving hours in the single-driver system was prolonged and that fatigue by night driving was significant. Variations of reaction time for subsidiary visual signals during driving by night confirmed effects of the monotonic vigilance task and significant effects of frequent short rests on recovery of fatigue-induced deterioration. A long rest in the middle of the route proved effective to help recovery in terms of variations in CFF level and subjective fatigue complaints. It is suggested that the limit of continuous driving time may be around 1–1·5 hours and that more short and long rests should be given.

Introduction

There are an increasing number of intercity truck drivers who are engaged in long hour night driving. This is due both to increased demand for freight traffic using expressways and to traffic regulations in large cities prohibiting in-flow of large size trucks in the daytime. These drivers are subject to fatigue developing in night hours as well as to disrupted driving performance linked with monotonic vigilance peculiar to expressway traffic.

Continuous driving of few hours or more is known to produce advance fatigue (Crawford, 1961; Laurell, 1976; Nozawa, 1975; Ohkubo, 1976). The night driving which is virtually affected by biological circadian rhythm and sleep loss may not only enhance the effects of fatigue but also accelerate performance deterioration. Although efforts have been made to prescribe regulations concerning limit of continuous driving time and related working conditions, there are few reports which deal specifically with possible regulations on night driving. (Horino, 1974; Nozawa, 1975).

The ' continuous driving time ' used here means driving hours without taking any rest. While the maximum speed limit on the expressway is formally provided in the government ordinance, there is no provision on the limit of driving hours. Even the notification by the Ministry of Labour issued on 9 February 1967 concerning the improvement of working conditions of road traffic drivers did not say anything about it, although an official tentative plan in 1962 on improvements of personnel management of long-distance truck drivers had indicated the necessity of such a limit (Nozawa, 1972).

In an attempt to elucidate physiological and psychological conditions of continued expressway driving at night, a field study was conducted on drivers of intercity trailers and large cargo trucks, special attention being paid to the influences of the single-driver system and to the effects of short and long rests taken in midnight hours.

Proceedings of 4th International Conference on Production Research (Tokyo) (1977)
JOURNAL? YEAR?

Method

The field survey was carried out for 27 truck drivers of five firms, of which 15 drivers were driving long trailers in the single-driver system and 12 were driving large cargo trucks in the two-driver system (Table 1). Their driving distance varied 250–570 km along an expressway between Tokyo and Osaka. During the whole driving time, heart rate, subsidiary reactions to a secondary task in which the driver was to identify correctly two kinds of visual signals displayed in front of the driving position, frequency of changing lane positions or operating the clutch pedal and results of direct observation of driving time and other events were recorded on jagent tapes.

Table 1. Type of trucks and number of subjects investigated.

Truck	System	Number of trucks studied	Number of subjects	Driving distance per one shift
Full trailer (18 tons)	Single driver	15	15	570 km
Ordinary cargo (11 tons)	Two driver	6	12	250–350 km
Total		21	27	250–570 km

Measurement of critical fusion frequency of flicker was conducted before and after short and long rests as well as before and after the shift. On these occasions, except short rests, feelings of general fatigue were also recorded for each driver by a questionnaire including 30 items of somatic and mental feeling proposed by the Industrial Fatigue Research Committee of the Japan Association of Industrial Health in 1970, the items being divided into three categories according to factor analytic studies (Kogi, *et al.*, 1970).

Some intra-cab noise and atmospheric conditions during driving were also measured. Then a questionnaire survey for over 1000 truck drivers was also performed to confirm the results of the field study.

Results

General fatigue by long-hour night driving

Most of the intercity truck drivers began their work shift at their home terminal after 19:00 and finished their shifts at 7:00–8:00 the next morning as a rule. Figure 1 shows the terminal-to-terminal hours, and percentages of actual driving hours to terminal-to-terminal hours in the single-driver system and the two-driver system. The average terminal-to-terminal hours for the single-driver system was 11.8 hours ranging between 10·1 hours and 12·9 hours, mean actual driving being 8·8 hours. The average terminal-to-terminal hours in the two-driver system was 10·5 hours, while the actual driving hours per person for the two-driver system varied from 3·9 hours to 5·9 hours, the average being 4·7 hours. Thus the ratio of actual driving time to terminal-to-terminal hours was 67·2–86·6% for the single-driver system (the average 75·3%) and 35·5-54·7% for the two-driver system (the average 44·%). In the case of the

single-driver system, often the drivers from two different cities exchanged their truck at a shuttle station located on the middle of the route. It is suggested that work under the single-driver system was more concentrated than that under the two-driver system as is pointed out by Nozawa (1973).

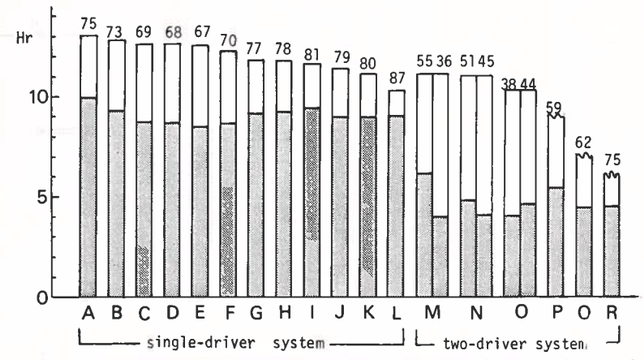

Figure 1. Comparison of driving hours of different working shifts in the single-driver system (A–L) and the two driver system (M–R). Numbers indicate percentage of actual driving time (▨) in the time required for the driving.

It should be noted that none of the drivers took any sleep at the sleeping facilities of the shuttle station. Instead, when they arrived at the service area nearest to the downtown terminal earlier than scheduled in the morning, they took short naps in the cab. A reason for this was the strong traffic regulations for these large vehicles in the city areas. Due to the driving at a constant speed on the expressway, which was generally between 80–100 km/hr on the average, drivers operated the clutch pedal less frequently (once per 2·0 min on the average), than in the downtown (once per 0·3 min on the average). Such a stable flow of operations on the expressway was likely to make the driving monotonous, which is particularly the case in the darkness. This was shown by lowered heart rate levels observed during the night driving as already reported by other authors (Dureman, 1972; Hildebrandt *et al.*, 1974; Laurell, *et al.*, 1976).

Intra-cab environment was characterized by the constant and high noise level of 85–102 dB(A) and irregular temperature distributions. Temperature at the driver's lower leg level was higher than at face level, in comparison with outside air. It is noted that the present cab-over type truck, which has its engine compartment under the driver in the driving position, is apparently causing a direct heat and noise exposure to the driver (Horion, 1974).

The mean rates of each subjective feeling of fatigue for truck drivers before and after driving is shown in Fig. 2. The number of subjective fatigue compliants considerably increased after driving. The mean frequency for the total 30 items increased from 2·7% before work to 21·1% after work. The mean rate of the first category (dullness and drowsiness) increased the most from 1·8% before work to 35·2% after work. The second highest compliants were indicated in the third category (physical discomfort). Increase in the frequency exceeding 40% of 26 drivers was distinct for such items as ' feel

tired in the legs', 'feel muddled', 'feel eye strain', and 'feel stiff in the shoulders'. Particularly it was over 60% for such items as 'feel eye strain', and 'feel stiff in the shoulders'. Predominance of localized fatigue feeling of the drivers should be noted.

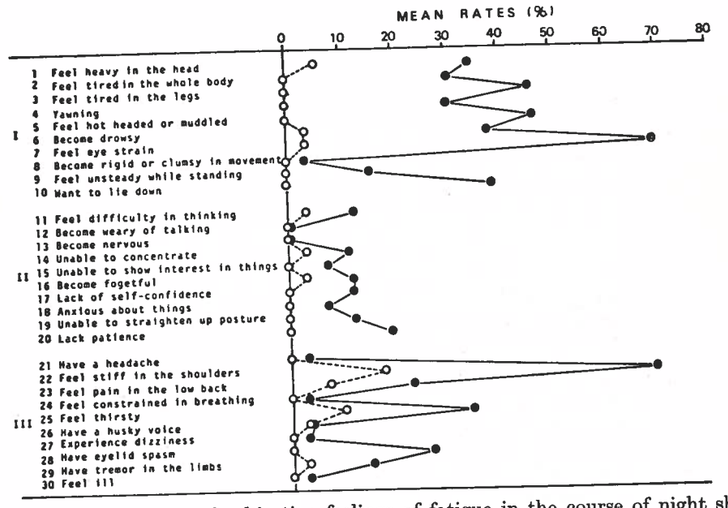

Figure 2. Mean rates of subjective feelings of fatigue in the course of night shift for truck driver before work (○) and after work (●). Number of subjects investigated before work was 28 and 26 for after work.

Effects of short rests

An example of the relationship between reaction times and short rests in the single-driver system is shown in Fig. 3. Large dots linked together show variations of mean reaction times for every 10 minutes periods. It is clear that before and after taking short rests, the reaction times changed significantly, demonstrating that taking rests has a meaningful effect on the recovery from fatigue brought about in driving the expressway at night.

Figure 4 shows cumulative frequency distributions of reaction times for three successive 30-minutes driving sessions. It is indicated that nearly 80% of the reaction times during the third session were longer than the median value for the first session. The differences in the distributions between the first and third sessions was significant (Laurell *et al.*, 1976). These results are evidence that frequent short rests are effective to prevent performance deterioration in the midnight driving. A suitable limit continuous driving may be inferred on the basis of this diagram to be shorter than two hours, preferably around 1–1·5 hours.

Effects of long rests after several hours of driving

Mean rates of each category of subjective fatigue feelings before and after a long rest are given in Fig. 5 for both the single driver and two-driver system. The results suggest that a long rest in the middle of the route was effective enough to reduce fatigue feelings. The mean rates for total items for drivers

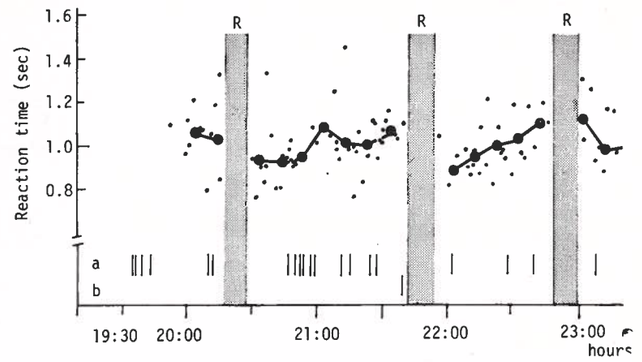

Figure 3. Variations of reaction time measured as a secondary task during driving in the single-driver system. Thick lines show mean variation. R indicates rest period, *a* indicates omission of the reaction, and *b* mistaken response.

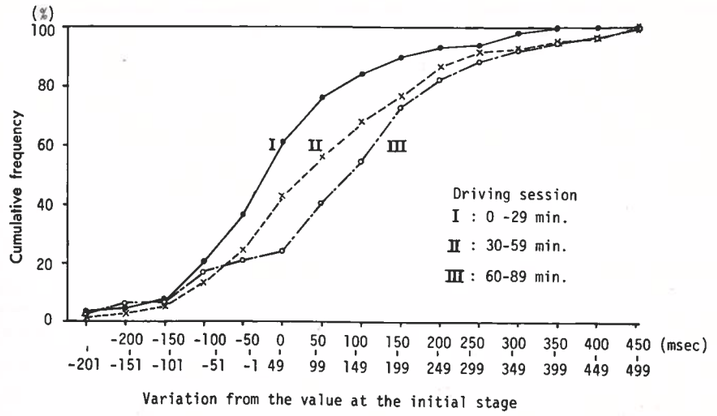

Figure 4. Cumulative frequency distribution of variation of reaction time for subsidiary visual signals from the value at the initial 30 min period of driving for four night shifts along the expressway in the single-driver system.

of the two-driver system, for example, showed a large decrease from the 25% before the rest to the 10% after the rest. A similar tendency can be observed for drivers of the single-driver system, though the recovery by a long rest was more marked for drivers of the two-driver system. The reason for the difference may be related to the fact that drivers in the two-driver system did not take any short rests along the route, while drivers in the single-driver system took 5–6.

Figure 6 shows a general tendency for the level of the C.F.F. value to decrease until a long rest at the terminal station in the middle of the route and to recover after this long rest, and again to decrease to a level lower than the level before the rest.

When the drivers arrived at their home terminal, the CFF fell once and gradually recovered toward the resting level. The vigilance task of driving at a constant speed along the expressway in the darkness may be an important factor causing the decrease of the cerebral activity level in driving. The similar variation has been reported in railway locomotive driving (Kogi, 1968). Significant recovery of the arousal level after a long rest confirms the necessity of taking sufficient rest.

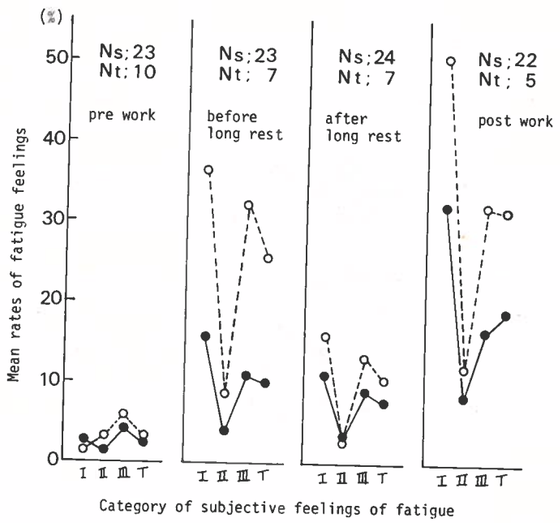

Figure 5. Mean rates of subjective feelings of fatigue in the course of a night shift for truck drivers in the single-driver system (●) and the two driver-system (○). Ns and Nt indicate the number of drivers studied for the single and two-driver systems, respectively.

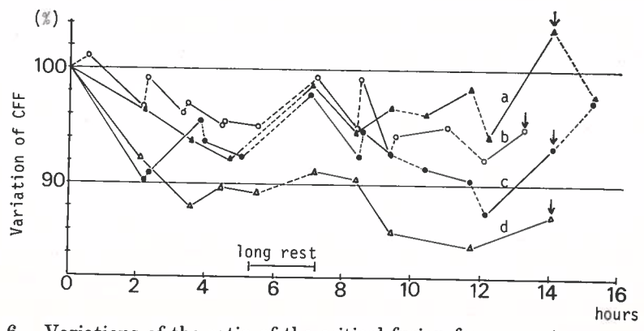

Figure 6. Variations of the ratio of the critical fusion frequency to pre-work value as a function of time elapsed from the shift beginning in the single-driver system. The diagram show variations for 4 truck drivers. The mark ↓ indicates the shift end. Dotted lines indicate rest periods.

Drivers' attitude toward the working systems

Truck drivers' attitudes were analyzed as regards the single-driver system, limit of continuous driving time, drowsy driving and occupational ill-health.

Concerning the work load of the single-driver system as compared with that of the two-driver system, 28·3% mentioned ' very much harder ' and 20·5% mentioned ' comparatively harder '. Thus, about half of the drivers complained of increased work load by the single-driver system.

Table 2 shows opinions of truck drivers on the continuous driving hours on the expressway. A limit of two hours ranks first, three hours second, and one hour third. When answers for 2 hours and 2·5 hours are put together, a limit of two-three hours ranks first. Thus, a general tendency of drivers is to prefer a limit of about two hours or less, although a distinction between short and long rests may be necessary to interpert the results.

Table 2. Truck drivers' opinions on the continuous driving hours.

' How many hours do you think will be suitable for drivers as a limit of time of continuous driving for safe driving on the expressway ? '

a. 1 hour	218(19·4%)	f. 3·5 hours	32(2·9%)
b. 1·5 hours	62(5·5)	g. 4 hours	79(7·0)
c. 2 hours	267(23·8)	h. 4·5 hours	7(0·6)
d. 2·5 hours	106(9·5)	i. 5 hours	10(0·9)
e. 3 hours	229(20·4)	j. No answer	119(9·9)

In view of the ILO Convention 67 of 1939 (limit of continuous driving time of 5 hours) and the ILO's 1954 proposal providing a resting period of not less than 30 minutes to be taken between the 4th and 6th hour after the start of driving, absence of such regulations in this country must be criticized (Nozawa, 1975). Popularization of expressway driving, increased size of road vehicles, and spread of the single-driver system demand implementation of regulation of the limit of continuous driving hours. The vivid accounts of drivers also point to an urgent necessity of the regulation.

Asked about the relationship between sleep deficit, driving sleep, and accidents, 972 drivers or 86·0% replied that they actually had the risk of driving asleep. 89 or 7·9% saying they had such risks ' often ' (Table 3).

Main reasons for reducing sleeping hours are suggested to be (1) predominance of night drives, (2) traffic jams accelerated by increasing passenger cars and time-based traffic regulations as a result of this, (3) single-driver systems and frequent continuous driving applied as measures of rationalization and countermeasures against shortage of drivers.

Majority of the drivers were suffering from some degree of low back pain. Fifty-four percent of the drivers replied that they felt low back pain, and 53% claimed that they had to be absent from duty due to low back pain (Table 4). Such a high frequency of low back pain among the truck drivers suggests that it should be regarded as a kind of occupational disease for this type of work. This view is supported by the fact that 47% of the drivers had come to feel low back pain though they had no such pain before becoming a truck driver.

Working at night imposes additional load on drivers who are engaged in intense vigilance task of high mental strain. The questionnaire survey results

confirmed the well-known fact that occupational drivers working at night have a high rate of digestive organ disorders (Unten Rōdō Anzen Iinkai, 1973). Tooth troubles were found in more than half of the drivers, many having troubles indicating tooth socket disorders. As for gastro-enteric disorders, 27·4% complained of stomach-ache, 37·8% sour stomach, and 31·9% said they had experienced gastric diseases. These results point to the presence of chronic type of disorders among drivers, presumably due to frequent night works.

Conclusion

As the truck drivers move with the vehicle, they have less opportunity to take sufficient rest, compared with ordinary factory workers. Frequent night work and long-distance drives worsen the situation. Irregular sleeping time, sleep in unfavourable conditions such as sleeping in the cab, frequent disrupted sleep (especially in the daytime), and poor quality of sleep are considered to have adverse effects on the drivers.

Table 3. Drivers experience of driving asleep.

'Have you had the risk of driving asleep while on duty ?'

a. No, not at all	140(12·48%)
b. Yes, occasionally	832(73·6)
c. Yes, often	89(7·9)
d. No answer	69(6·1)

Table 4. Experience of low back pain of truck drivers.

'Have you ever suffered from low back pain so intense as to hamper the driving operation ?'

a. No	311(27·5%)
b. Yes, but only before I became a truck driver	8(0·7)
c. Yes, although I had not before I became a truck driver	532(47·0)
d. Yes, both before and after I became a truck driver	79(7·0)
e. No answer	202(17·8)

Decline in the perceptual and performance parameters during the night driving on the expressways was very noticeable. In this respect, the drivers of the single-driver system were apparently more handicapped than those of the two-driver system.

Because the short rests have favourable effects on the recovery from such functional deteriorations, a certain limit for a continuous driving period at night should be prescribed for these drivers. This limit would be no longer than two hours and possibly as short as around 1–1·5 hours, as suggested by the results of the present study.

On the other hand, a long rest in the middle of the route taken in addition to the above-mentioned short rests is suggested to be efficient enough to prevent the advancing fatigue due to midnight drives. This would mean that a sleeping period after driving hours is as important as regulations of working hours.

More attention should be paid to assurance of frequent short rests and of long rests enabling a certain length of substantial sleep interrupting the night driving.

High incidence of low back pain and tooth troubles as well as gastro-enteric disorders is regarded as a kind of occupational illhealth for this type of work, which requires irregular working hours and high mental strain.

In conclusion, following points seem to be realized for promoting safety and health of the intercity truck drivers.

(1) Drastic revision of traffic regulations on intercity large size trucks in favour of the improvement of the drivers' conditions.
(2) Restructuring of the working system of such drivers, emphasis being laid on the re-examination of such problems as the single-driver system and the predominant night drives.
(3) Improvement of driving and expressway conditions in order to facilitate taking short and long rests wherever these become necessary. Prescription of the limit of a continuous driving time and resting periods as well as improvement of resting facilities along the expressways are essential.

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PHYSICAL WORK LOAD ON AND DERMATOSES OF FEET OF DAM WORKERS STANDING ON AN INCLINED PLANE

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To Prof. A. Wisner,
With best wishes,
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Physical work load on and skin changes of feet of workers dealing with asphalt paving of a large rock-filled dam surface with an inclination of 27.5 degrees were investigated. While the operators of finishing machines stayed mostly on their machines, workers dealing with supplementary and miscellaneous work, all being elderly farmers working part time for a subcontractor, spent more than 70% of their working time standing on an evenly inclined surface. The work flow among these standing workers was restricted by the conditions of the finishing machines resulting in a variety of work patterns and in frequent changes in working positions. According to oxygen intake and heart rate measurements, work by standing workers was physically moderate but ascending and descending on the smooth slope were much more difficult than level walking. Feelings of general fatigue were more frequent among machine operators, while tiredness in the legs remarkably increased in standing workers. The latter had higher fatigue rates for the posterior part of lower legs, ankle, and sole than the former. Painful callosities and burn scars were frequently observed on the soles of the feet of standing workers. These symptoms are most likely connected to the peculiar standing postures on steep and smooth inclinations and with the heated asphalt surface.

Work on an inclined surface which occurs sometimes in industrial activities offers characteristic problems in terms of work load and safety. Studies on human performance on a slope have mainly be done in general working (DEAN, 1965) and in forestry where the work is physically difficult and even dangerous. FUJIBAYASHI *et al.* (1956) and TSUJI (1970) reported that the standing posture in relation to the slope angle was an important factor determining the working load and the energetic cost. It has been reported that a slope steeper than about 15 degrees

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becomes very unfavorable with respect to both energy expenditure (DEAN, 1965) and safe performance (ANMA, 1973). Restricted freedom of motion and psychological influence associated with work in a high place should also be taken into account (KANO, 1962). When the slope is quite even without any significant roughness, as in the case of a dam surface, the work on it seems particularly dangerous, the unstable posture and the slippery surface having strong influence on performance and safety.

Technical developments in construction engineering have made it possible in recent years to construct a dam in mountain areas near level land applying the rock-filled system. This type of dam surfaces demands unique asphalt-paving work to prevent water leakage at the upper-stream side of the dam. The paving work must be done on a very wide and steep even slope having an inclination of nearly 30 degrees which is believed to be an approximate upper limit for a man to be able to stand. Work on such an even slope should be greatly different from work on level ground. We have found fatigue symptoms and skin changes which were closely connected with the local loading of the legs and feet due to standing on the inclined dam surface.

MATERIALS

Work load and local fatigue symptoms of male workers engaged in construction of a rock-filled dam were investigated during a field study conducted in August 1972. The work consisted of paving and finishing of a mixed asphalt material on a large even slope inclined 27.5 degrees. Specially designed finishing and rolling machines were used which were hauled up and down by means of cables from a large winching machine fixed on the top of the dam. The asphalt material was heated in advance in a plant and carried to the top of the dam by trucks. It was then transferred into a moving dumper on the slope by means of a crane attached to the winch. The dumper was moved down the slope by cables, the asphalt material was put into a container on the finishing machine called a finisher. The material was heated again with propane gas to about 150°C. Amending and manual finishing work was necessary after the asphalt was paved by the finisher. The speed of pavement was 1–6 m/min, a pavement lane being 3 m in breadth and 160 m in length. Joint-compacters were used to make the joints of neighboring lanes compact. Finally vibrating rollers were used three times in order to compress and harden the surface.

The workers were divided into two groups; a group of machine operators who usually worked sitting on the machines, and a group of standing workers. The former included operators of the winch, finisher, and vibrating rollers. The latter worked on foot standing directly on the steeply inclined plane, doing the finisher-adjusting work, amending the pavement, raking, or manipulating the joint-compacters. All workers wore rubber-soled Japanese sneakers called *jika-tabi*.

The work of standing workers was considerably strenuous because they had to keep their posture on the steeply inclined slope the even surface of which was not at all rough. They often had to assume half-rising postures, and had to ascend and descend the slope because the temperature of the surface material immediately after being paved was as high as about 100°C or more. The paving work had to stop when it rained, so that it was necessary to start the pavement of the lane over again from the bottom in order to assure the homogenous quality of the pavement of each lane. A general view of the dam surface is shown in Fig. 1 with a dumper, a finisher, and a vibrating roller. Figure 2 shows examples of the standing postures of workers engaged in finisher-adjusting, raking, and joint-compacter manipulation.

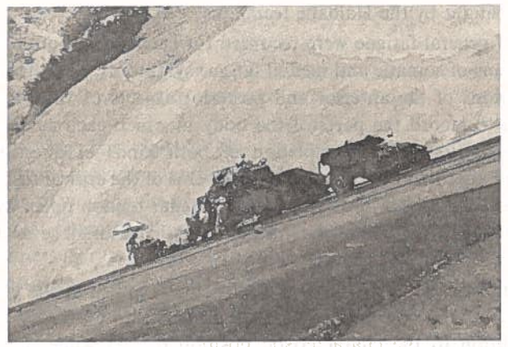

Fig. 1. Asphalt paving machines and workers on the slope of a rock-filled dam. From right to left, the dumper, the finisher, and the vibrating roller.

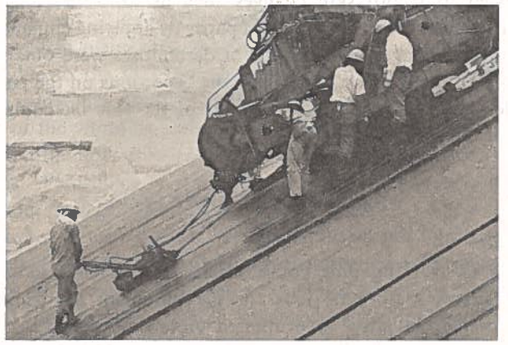

Fig. 2. Working postures of the standing workers on the slope surface. From right to left, two workers adjusting the finisher, a raking worker, and a worker manipulating a joint-compacter.

These workers worked 9 hours a day from 7.00 A.M. to 5.00 P.M. with a lunch break of an hour, except operators of vibrating rollers who worked until 6.30 P.M. Work at the dam site began in October 1971. Nearly one year was needed for the whole pavement work of the dam, pavement being completed in five layers of 6 cm in depth each. The average age of 16 machine operators studied was 28.4 years and that of 14 standing workers studied was 45.4 years.

Time study was conducted on 5 machine operators and 7 standing workers by recording the stop-watch readings for every part of the work. For 4 subjects, the heart rate during work or while walking on the slope was recorded by means of telemetering the electrocardiogram and recording it on an ink-writing oscillograph. Oxygen intake was measured by sampling the expired air in Douglas-bags and analyzing it by the Haldane technique.

Feelings of general fatigue were recorded for each worker on a questionnaire including 30 items of somatic and mental fatigue symptoms. Another check-sheet having illustrations of the anterior and posterior aspects of various parts of the body was used to record the parts of the body in which each subject recognized local fatigue sensation. The completion of both kinds of questionnaires was done before and after a day's work. Measurements of the critical fusion frequency of flickering red light and of the threshold of patellar tendon reflex were also performed before and after work, the former being measured several times also during work.

In the course of the field study, which originally aimed at the general assessment of the work load, we noticed that the fatigue was especially prominent in the legs in relation to the characteristic position of feet while standing on the inclined surface. This led us to investigate the skin changes of the sole of the feet of standing workers. The soles of the feet of 9 standing workers were inspected and photographed to record skin changes such as callosities and burns. An imprint of each sole was taken on a sheet of paper by applying cinnabar seal ink on the whole sole. Percentages of each type of dermatoses were obtained for each of the 13 sections of the sole, *i.e.*, 5 toe sections, 3 sections on the pad of the fore part of the sole, 2 sections on the central part of the sole including the hollow, and 3 sections of the surface of the heel.

DISCUSSION OF RESULTS

Time study results

Table 1 shows working time composition for different kinds of machine operators' and standing workers' jobs for the pavement of the inclined dam surface. The total observation time differed among jobs because it sometimes happened that the time study was interrupted by rain which forced stoppage of work. As a matter of fact, work on the wet and slippery surface was very dangerous and could hardly be carried out. In the table, main work means the primary

Table 1. Working time distribution of asphalt paving work on an inclined dam surface.

Component	Machine operators			Standing workers			
	Finisher operator	Vibrating roller operator	Winch-portal operator	Finisher adjusting	Joint-compacter	Amending	Raking
Observation time(min)	303	188	187	448	172	395	383
(Number of persons)	(2)	(2)	(1)	(2)	(1)	(2)	(2)
Main work	21.9%	48.6%	27.3%	26.1%	25.0%	22.6%	20.0%
Complementary work	18.9	2.5	1.6	14.3	7.6	22.5	6.2
Preparatory work	3.3	5.8	0.5	2.7	2.3	6.8	8.4
Other works	8.7	13.8	0.5	25.7	46.5	29.3	16.9
Waiting	18.8	16.5	46.5	2.7	4.1	16.2	42.1
Rest	16.5	6.4	23.5	28.6	4.7	2.7	6.3
Unknown	11.9	6.9	—	—	9.9	—	—
Working position							
on the slope	100.0	94.2	0.0	81.0	76.7	74.7	61.6
on the level	0.0	5.8	100.0	19.0	23.3	25.3	38.4

production work for that kind of job. It includes hand-wheel operation for a finisher operator, ascending and descending operation of a vibrating roller, control operation of winding the up and down cables of the dumper and the finisher for a winch-portal operator, fine adjusting of the machine direction and of the pavement thickness for a finisher-adjusting worker, manipulation of a joint-compacter, control by shovel of the material flow from the finisher to the dam surface for an amending worker, and smoothing of the paved lane using a rake for a raking worker. Complementary work of the table means incidental and subsidiary work intervening between those main operations except for preparatory work.

It can be seen from Table 1 that the percentage of main work was rather low on the whole between 20 and 27%, except for operators of the vibrating roller who were engaged in main work during nearly half of the working time. This was primarily due to the fact that the paving work flow was restricted by the finisher which sometimes came to a standstill due to various sorts of trouble. The operation of the vibrating rollers, on the other hand, could be conducted independently from the flow of work, so that the percentage of main operation was high for rollers. Percentage of complementary work was relatively high for the finisher operation, finisher adjusting, and amending work. These three jobs were closely connected with each other. When the finisher got into some trouble and the constant flow of work was disturbed, the operator was busy performing checks, adjusting cables or burners, and giving instructions to others, while the standing workers helped adjusting the machine, arranged or cleaned tools, moved around smoothing the surface, connecting and disconnecting their safety ropes. While the rate of waiting time was high for the winch-portal operator and rakers, the difference between the machine operators and the standing workers as a whole was

noticeable in comparison to the percentage of other works, the latter workers undertaking other miscellaneous works more frequently than the former. This might be connected with the difference in the working skills and in the employment system; the operators were permanent employees of the construction company and specially trained, and the standing workers were temporary employees of the subcontractor who were all farmers working part-time. Thus doing miscellaneous tasks was expected to the latter, the tasks being variable according to the momentary flow of work and to the instructions of operators. As a result, moving on foot on the inclined surface was very frequent among standing workers.

If the percentage of actual working time was calculated as the sum of percentages of main, complementary, preparatory, and other works, it was the highest for joint-compacter work (81.4%) and for amending (81.2%), followed by roller operation (70.7%), finisher adjusting (68.8%), finisher operation (52.8%), raking (51.5%), and winch-portal operation which had the lowest value of 29.9%. A considerable part of the waiting time of the winch-portal operator was spent watching operations of the dumper and the finisher.

Percentage distribution of the working positions is shown in the lower part of Table 1. Operators of machines spent their working time mostly on the machine which had its own level floor. The percentage of time spent by standing workers on the inclined plane was lower, varying, from 62 to 81%. These workers tried to get off the inclined area particularly when the finisher neared the top or bottom of the dam. When the finisher was in operation midway, along the slope, however, the standing workers were obliged to stay on the slope, it being safer to stay near the finisher than walking around the slope whose cooled and hardened surface was very slippery. Resting or waiting was done on the slope often in a squatting position with the back showing the hillside.

Results of the time study indicate that the standing work on the inclined dam surface may be greatly dependent upon the operation of the finishing machine. Not only the main work but also most of other secondary work of the standing workers must be done while standing and walking on the slope. This contrasts with the working positions of the machine operators who rarely stand on the slope. It seemed common to all the standing workers to move frequently on the slope. This kind of situation will produce various kinds of physiological and psychological effects on the workers, especially in relation to keeping postures peculiar to such a slope.

Oxygen intake and heart rate level

Oxygen intake and average heart rate increase during the main part of the work and during walking on the inclined dam surface are shown in Table 2. Oxygen intake and heart rate increase were relatively small for workers handling machine operations such as roller work, while the main types of the standing work on the slope belonged to physically moderate work. Thus the heart rate increase

Table 2. Oxygen intake per working minute and average heart rate increase from the resting level for main types of work on the dam sufrace.

Type of work	Subject	Stature (cm)	Body weight (kg)	O_2 intake (ml/min, STPD)	Average heart rate increase (beats/min)
Vibrating roller operation	A	177	69	511	6.3
Finisher adjusting	A	177	69	1000	10.5
Amending	B	158	47	596	20.3
Raking	C	175	65	1330	34.2
Ascending 1.3 m/sec	A	177	69	2150	75.6
1.2 m/sec	C	175	65	2290	101.9
0.7 m/sec	D	165	60	1770	78.7
Descending 1.4 m/sec	A	177	69	1170	40.0
1.4 m/sec	C	175	65	1040	71.8
0.4 m/sec	D	165	60	836	40.1
Level walking 1.4 m/sec	C	175	65	820	30.4
1.5 m/sec	D	165	60	1210	29.7

for the main standing work was around 30 beats/min or less. Raking which was done mainly in a forward bending posture seemed more difficult than other types of surface work.

In the case of ascending and descending the slope, the physical load was far more pronounced. Descending proved to be even difficult than level walking, which confirms data by McDONALD (1961) showing increased energy expenditure for walking downhill above 20 percent grade. Ascending the slope on foot demanded a high oxygen consumption of around 2 liters/min, producing a large heart rate increase. Because of frequent ascending and descending of a small distance during any type of standing work, the actual working intensity of standing workers was estimated to be often higher than the values indicated in the table.

Examples of heart rate change during walking on the slope are shown in Fig. 3 for three subjects. As shown in the figure, descending produced a heart rate level reaching about 120 beats/min which was higher than that in usual level walking. This implies that descending the steep, even surface may not necessarily be easier than usual level walking, presumably because particular control of the walking posture and of leg motion may be required for descending such a completely even slope. Ascending usually produced markedly high heart rate levels exceeding 160 beats/min within 1–2 min, so that recovery took place only gradually. Ascending seemed to be very strenuous also because stepping forward with the foot pivoted was very unusual and hard to control.

Subjective fatigue feelings

The average rates of subjective feelings of fatigue before and at the end of work are given in Table 3 for the two workers' groups. The 30 items in the table

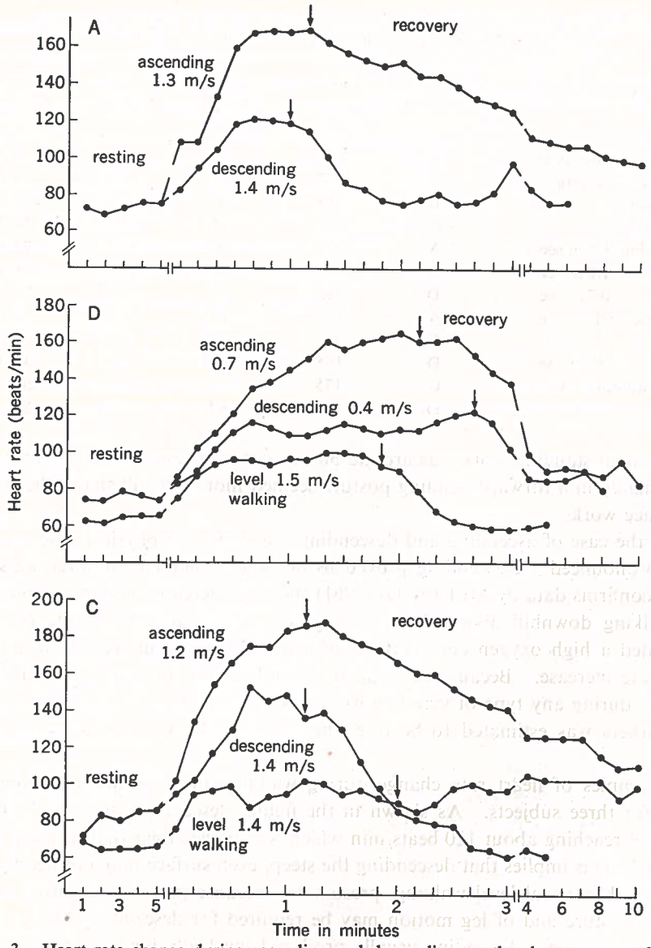

Fig. 3. Heart rate change during ascending and descending on the slope, compared with level walking, for subjects A, D, and C. Arrows show end of walking.

are those proposed by the Industrial Fatigue Research Committee of Japan Association of Industrial Health in 1970, the items being divided into three categories according to the factor-analytic studies of SAITO *et al.* (1970) and KOGI *et al.* (1970). Machine operators complained of fatigue in general more frequently than standing workers for each of the three categories. In many items, including tiredness of

the whole body, drowsiness, shoulder stiffness, and low back pain, the average rate for machine operators decreased after work, whereas there was a common tendency of the average rates of almost all items to increase in the case of standing workers except for drowsiness and lack of patience. This suggests that the machine operators tended to feel tired even before work. Early start of the day's work and long daily working hours especially for vibrating roller operators should be taken into account.

The most prominent difference between the two groups, however, is the fact that the machine operators most frequently checked the 'eyestrain' item after work while the most frequently checked item for the standing workers was 'feel tired

Table 3. Mean rates of subjective feelings of fatigue for machine operators and standing workers before and after work.

Category	Item	Machine operators		Standing workers	
		before	after	before	after
I	Feel heavy in the head	34.2%	26.3%	8.7%	17.4%
(Dull-drowsy	Feel tired in the whole body	50.0	34.2	21.7	21.7
factor)	Feel tired in the legs	44.7	47.4	43.5	65.2
	Yawning	34.2	42.1	4.3	26.1
	Feel hot headed or muddled	31.6	42.1	13.0	17.4
	Become drowsy	60.5	21.1	30.4	4.3
	Feel eye strain	21.1	60.5	21.7	47.8
	Become rigid or clumsy in movements	5.3	15.8	4.3	8.7
	Feel unsteady while standing	13.2	21.1	4.3	8.7
	Want to lie down	28.9	26.3	13.0	13.0
II	Feel difficulty in thinking	5.3	10.5	0.0	0.0
(Factor of	Become weary of talking	2.6	7.9	8.7	13.0
difficulty in	Become nervous	10.5	5.3	8.7	13.0
concentration)	Unable to concentrate	13.2	10.5	8.7	8.7
	Unable to show interest in things	21.1	18.4	0.0	0.0
	Become forgetful	10.5	15.8	8.7	13.0
	Lack of self-confidence	0.0	5.3	0.0	4.3
	Anxious about things	5.3	10.5	4.3	4.3
	Unable to straighten up posture	10.5	2.6	4.3	0.0
	Lack patience	26.3	18.4	8.7	13.0
III	Have a headache	10.5	26.3	0.0	13.0
(Factor of	Feel stiff in the shoulders	50.0	44.7	13.0	21.7
physical	Feel pain in the low back	42.1	36.8	26.1	34.8
disintegration)	Feel constrained in breathing	13.2	10.5	8.7	13.0
	Feel thirsty	21.1	21.1	8.7	13.0
	Have a husky voice	2.6	5.3	0.0	0.0
	Experience dizziness	7.9	5.3	0.0	4.3
	Have eyelid spasm	15.8	28.9	4.3	13.0
	Have tremor in the limbs	2.6	5.3	8.7	13.0
	Feel ill	18.4	13.2	0.0	8.7
	Number of cases	38		23	

in the legs.' The complaint of eyestrain among machine operators increased from a mean rate of 21.1% before work to 60.5% after work, while that among standing workers increased from a nearly equal level of 21.7% before work to 47.8% after work. The tiredness in the legs, on the other hand, increased for machine operators only by 2.7% from 44.7% to 47.4%, but it remarkably increased for standing workers from 43.5% before work to 65.2% after work.

It should be noted that the standing workers were relatively older than machine operators and that the standing workers were all farmers working part-time. The relatively low rates of fatigue for the standing workers might have been associated with such differences. The above-mentioned contrast between the two groups of workers for eyestrain and leg tiredness might have resulted from the difference in the type of work. In particular, the very high mean rate of the leg tiredness among standing workers is conspicuous, since the rate of other related

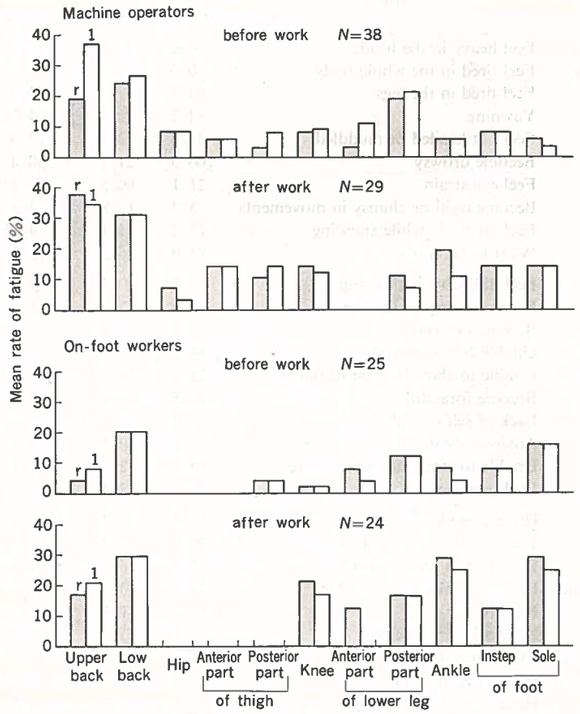

Fig. 4. Mean rates of local fatigue feelings at various body parts before and after the inclined-plane work, r: right side, 1: left side.

items such as tiredness of the whole body, yawning, and shoulder stiffness was comparatively small among them.

Figure 4 shows the mean rates of local fatigue feelings at various body parts before and after work for the two workers' groups. It is clear from the figure that the machine operators felt fatigue at various body parts even before work and that the standing workers tended to complain of local fatigue less frequently. The local fatigue feelings were the most frequent in the upper and low back regions of machine operators, the mean rate exceeding the 30% level. In contrast to machine operators, the standing workers had higher mean rates for the posterior part of lower legs, the ankle, and the sole especially after work. The fatigue of the knee was also frequent among standing workers, while none of them complained of local fatigue in the hip and the thighs. These results strongly suggest that localized fatigue frequent among standing workers should be attributed to their peculiar standing posture which produced particular local stress on the lower legs and feet.

The quality of the tiredness of the legs would thus be assumed to be very different between the two groups of workers; while the tiredness was felt by machine operators diffusely along the legs, the tiredness felt by the standing workers was localized in the leg regions below the knee level, the ankle and the sole of both feet comprising center areas of the leg tiredness sensation. Generally speaking, no laterality was found in these respects.

Dermatoses on feet of standing workers

The above results indicate that the quality of fatigue may be considerably different between the operators of construction machines and the part-time workers who stand while working all day. Although the measurements of functional tests such as the test of critical fusion frequency of flickering light and the threshold measurement of patellar tendon reflex gave no consistent results for either of these two groups, the investigation of the subjective fatigue has revealed that the fatigue of standing workers was associated with the peculiar standing posture necessitated by the work on the steep, smooth slope. The fatigue feelings of machine operators might be related to rather monotonous operation of the machines in a continuously sitting posture.

The standing workers of the present study told that the maintaining of the standing posture on such a steep inclination was not only fatiguing but often very painful due to constant irritation of the feet. Such painful sensation was apparently relevant to the observed high rate of subjective fatigue predominant in foot regions. As causes of pains these workers mentioned unavoidable irritation of ankles and soles while standing, formation of painful calluses, and burns on the soles of their feet. They mentioned that foot pains were especially remarkable from the second month of the inclination work until the third or fourth month. After these months they seemed to be relieved from severe pain and became more

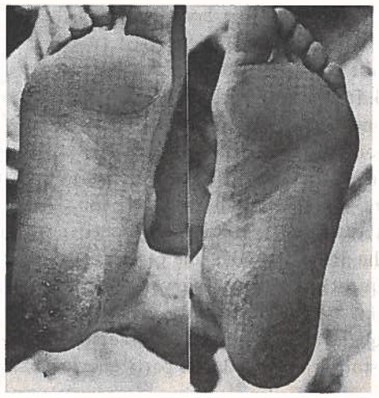

Fig. 5. Callosities on sole caused by working on the slope.

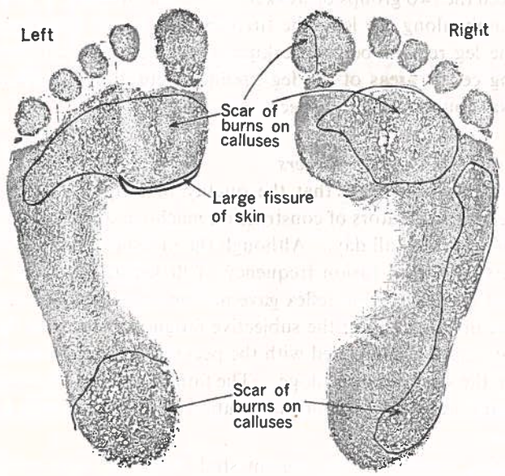

Fig. 6. Footprints showing burns and callosities of a standing worker.

or less accustomed to standing work on the slope. The period of severe pain might have resulted from formation of calluses on feet and from recurring burns caused by walking on heated asphalt. Calluses thus formed remained as long as a worker continued working on the slope and would disappear within six months or so after the worker returned either to farm work or to usual construction work.

Callosities on feet of a male operator of age 29 who often did the work of

a standing worker are shown in Fig. 5. Callosities were remarkable on the heel, the pad of the fore part of the foot corresponding to the metatarso-phalangeal joints of the toes, and the enlarged ends of the toes. The callosities were thicker on the great toe, the medial part of the pad of the fore part, and the lateral and medial parts of the heel. The marginal ends of the callosities of these parts were so thick that they looked like they were projecting sharply from the neighboring skin surface or like a round edge. The skin external to the hollow of the sole of the feet also had callosities, though they were not so thick as in the above-mentioned parts.

Figure 6 shows the imprint made with cinnabar seal ink of the soles of both feet of a standing worker age 46 taken on a sheet of paper. Callosities were also prominent in this subject on the heel, the fore pad, and the great toe of both feet. Small round and irregular spots on these parts and on the lateral end of the right sole corresponded to scars caused by blisterings due to recent burns. A large

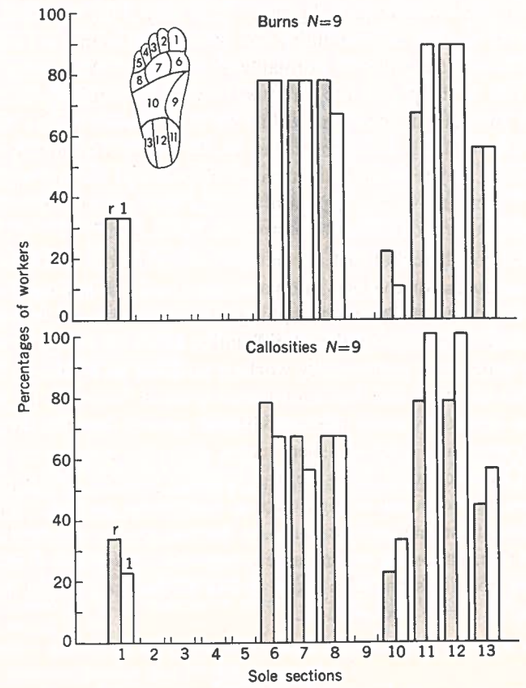

Fig. 7. Percentages of workers with burns and callosities on the sole of inclined-plane workers.

fissure of the skin was observed along the dorsal end of the callosities on the pad of the fore part of the left foot. The subject mentioned that the fissure part was very painful and that it had been gradually formed in accord with the development of the callosities.

Percentage of standing workers with scars of burns and with thick callosities are indicated in Fig. 7 for the 13 divisions of the sole of both feet. It is clear that burns as well as callosities were frequent on the pad of the fore part of the sole and the surface of the heel, the percentages being almost equal for the right and the left sole. Formation of thick callosities were also seen on the ball of the great toe and the skin external to the hollow of the sole where burns were sometimes observed.

MIURA (1957) reported that pressure of the metatarso-phalangeal joint part of the sole and of the center of the great toe increased when the heel height was elevated in wearing a high-heeled shoe. The pressure level of these parts reached 3–4 kg/cm² for the heel height of 4 to 5 cm or more, while pressure of the surface of the heel decreased to less than 2 kg/cm². This may imply that the distribution of the pressure of the sole while standing and walking on an inclined surface would also be very different from that of normal level standing. As a result, the skin of the great toe and of the pad of the fore part of the sole would receive unusual irritation. The pressure distribution within the heel surface would likewise vary according to the standing direction of feet on the slope. Recurring irritation of mechanical nature may result in formation of callosities on the sole which are often very painful. These are similar to painful calluses seen on feet of workers standing all day, as reported and discussed by SCHWARTZ *et al.* (1957).

One should note here that such dermatoses on feet are not usual for the asphalt paving work conducted on the level or on a sloping road. Usual road construction workers may be able to easily avoid stepping on heated surface, while the work on an evenly inclined steep slope makes it difficult to avoid the hot areas, the hot but sticky surface being even preferred by workers to stand on to have a more secure foothold. This situation may be also relevant to small burns on the skin of arm, neck, and face caused by small pieces of heated asphalt material flying from the dumper or the container of the finisher. Since heat may produce on the soles the same effect as by mechanical pressure, the standing workers of the present study had been apparently exposed to high risks of dermatoses on feet. The presumed combined effect of mechanical pressure and heat may be evidenced by very high percentages of thick callosities accompanied with burn scars on feet of these workers. Many machine operators had also more or less diffusely developed callosities on feet, but burns were rare among them.

CONCLUSION

In conclusion, the characteristic aspects of the work load of workers standing on an evenly inclined steep slope may be represented by the variety of unstable working postures, by strenuous efforts associated with ascending and descending, and by fatigue concentrated in the lower leg and foot regions. Dermatoses localized on the sole of workers is evidence of such a unique kind of loading. Because the main part of asphalt paving has been mechanized, the manual work itself does not seem necessarily strenuous. The dependency of the work on the finisher operation as well as the restriction of the working postures, however, resulted in very irregular working patterns of those standing workers and in very high rates of localized symptoms.

The concomitant effect of heat on the feet of standing workers indicates another characteristic aspect of the working system of the seemingly highly mechanized asphalt paving. It was apparent that heat locally applied to the sole of workers helped develop not only fatigue of the legs but also dermatoses which were so painful in the first months of the pavement work. The described asphalt paving system may be an example of incomplete mechanization which may demand a variety of supplementary manual labor but without previous deliberations on the working habits of the workers and on the inconveniences to them. Devising a level platform to be attached to the finishing machine or the provision of heat-proof shoes, for example, would have greatly ease the workers' load and prevent possible harm. Working postures similar to those of the standing workers on the dam surface are occasionally seen in other industrial activities such as roofing and forestry work. The present results indicate that to properly assess the working load of these workers care should be taken to clarify the possible effects of postures restricting working habits. More information is needed to explain the complex relationship between characteristic working postures and the integrated work load.

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ENVIRONMENTAL FACTORS AND WORK PERFORMANCE OF FOUNDRY WORKERS

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to Prof. A. Wisner
With best wishes,
Sadao Horino

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Environmental factors such as atmospheric conditions, lighting, noise, and dust in foundry factories of different sizes were evaluated by direct physical measurements and a subjective rating method using an ergonomic checklist. Working postures and subjective feelings of fatigue of the workers were analyzed in various types of foundry shops. The results showed that work load was highly connected with poor working postures and unfavorable arrangement of work space as well as with poor work-place environment, particularly in terms of dust and noise. Forward bending and squatting positions, which were attributable to the manual working height on or just above the floor level, occupied 70–90% of the actual working time handling large-sized casts, while the work using a table allowed workers more frequent erect standing postures. It seemed essential to redesign the fundamental working processes and to improve the work surface height. A comparison was then made as to performance patterns and electromyographic activities of main muscles between the traditional molding work on the floor and the work at a newly developed hydraulic lift-table operated by foot pedals. The new table assured the worker of an optimal standing position and proved to be an effective means of redesigning the work space.

Like in other manufacturing industries, the workshop environment in foundries comprises many hazardous factors. In spite of technical progress that has taken place, major safety and health problems of foundries remain just as before. Occupational injuries and diseases such as low back pain are closely related to the type of the foundry work systems and to their environmental factors in which the space arrangement may be included. The problems involved in these factors have not been solved by existing installations of such foundries which are partially automated.

It has become less and less attractive for young workers to seek jobs in a foundry. This is reflected on the very disproportionate age composition of foundry workers, more than 60% of them being over 40 years old (HORINO, 1975). On

the other hand, molding work which is a major process in a foundry often requires long-term skills and hence maintains traditional work methods. Many kinds of molding work are performed at the floor level, handling of heavy materials being done in deep bending or squatting postures. As a result, the majority of such workers suffer from low back pain (HORINO, 1976).

The purpose of this paper is to assess the environmental conditions of foundries in relation to work performance, and to propose some practical solutions from ergonomic points of view. A comparison was made between the traditional molding method and the automated line processing. The former was then compared with a new method using a newly designed worktable whose height was adjustable.

METHODS

A field survey was carried out in five foundry firms. Their products were parts for diesel engines, parts for hydraulic devices, parts for food processing equipment or home appliances. The number of workers in a firm varied from about 30 to 130.

Physical measurements of atmospheric conditions, illumination, noise, and air borne dust concentrations were conducted. Then of all the major workshops, two automated processing lines and fifteen manual workshops were chosen for the study. Subjective evaluation of environment using 50 pairs of adjectives was made by each worker. Subjective feelings of fatigue were recorded for several days by each worker before and after a day's work. Further, ergonomics checklist which had been developed as a rating method for working systems (KOGI *et al.*, 1973) was used by ten ergonomics specialists.

A motion and time study was undertaken in order to study the relative frequencies of various working postures and durations of these postures. Combinations of the eye and hand height at work in various situations were also recorded. Electromyographic activities of the back, shoulder, and abdominal muscles were recorded and analyzed in an attempt to compare the relative muscular load between three basic working positions; working on the floor, working at a table of fixed height, and working at an adjustable table of the optimal height.

RESULTS

It was commonly found, regardless of the size of the enterprise and the kind of their products, that exposure to high dust concentrations and high noise levels were primary environmental problems; dust concentrations varied between 3–38 mg/m^3, and noise level ranged between 70 and 100 dB (A) or more, pneumatic devices causing noise levels of 90–110 dB (A). Illumination was another factor to be improved, because illumination levels below 100 lx were frequently found and dust in the air often accounted for insufficient lighting. Due to absence of systematic

ventilation and air-conditioning systems, the temperature was usually close to that of outdoors.

An ergonomic checklist consisting of nine chapters and 334 items was used to evaluate two kinds of workshops, *i. e.* conveyor line shops and manual molding shops. The frequency of items checked by more than half of the checkers in each chapter is indicated in Table 1. The chapters in which more than 50% of the items were checked by the majority were the chapter on work space, that on environment, and that on dynamic workload. The frequency of items checked for the conveyor processing was higher than that for manual working as to chapters concerning work space, controls, displays, and environment. Only in chapters on postural and static workload and on dynamic workload, the frequency for the manual work was higher than that for the line processing. This means that an automated molding system with a high productivity does not necessarily provide for better workplaces from ergonomic points of view.

Profiles of subjective ratings of the environment by workers according to the semantic differential method were different between two types of workshops, as shown in Fig. 1. Workers of the automated lines described their environment as dustier, noisier, and narrower than people of other shops did. The automated line workers also evaluated their environment as rather confined, tiresome, boring, heavy, hard, and irritating. It was noted that workers making much noise felt relatively noiseless than those making less noise in their work, as mentioned previously by MATSUI *et al.* (1969). It was found that noise and dust of some workplaces, such as those with molding machines and frame breaking machines, affected all the other workers in the same building.

The relation between eye height and hand height during work is shown in

Table 1. Frequency of items checked by more than half of the checkers (9–10 ergonomists) from ergonomic points of view in the manual molding work and the line process molding work.

Chapter	Number of items	Manual work (%)	Line process work (%)
1. Work space	22	50.0	90.9
2. Seat and foot rest	26	7.7	42.3
3. Controls	56	14.3	28.6
4. Information displays	36	5.6	25.0
5. Combination of displays and controls	37	2.7	35.1
6. Working environment	50	52.0	68.0
7. Posture and static work load	39	48.7	46.2
8. Dynamic work load	35	82.9	74.3
9. Hours of work and work performance	33	45.5	45.5
Over all	334	33.5	48.5

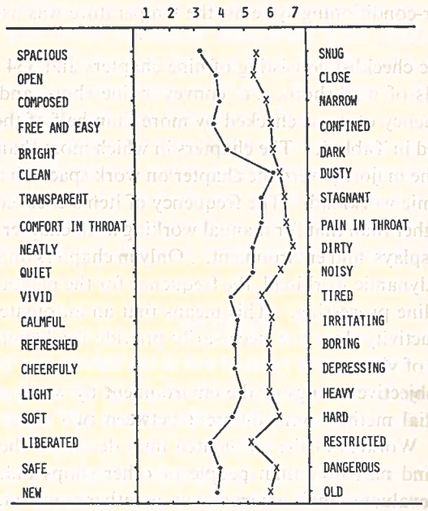

Fig. 1. Profiles of subjective ratings of the environment by the manual workers (●) and the automated process workers (×).

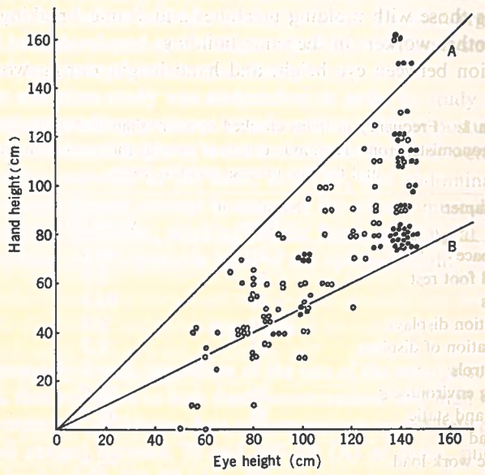

Fig. 2. Combination of eye height and hand height during conveyor line work (●) and during manual work on the floor (○). Lines A and B indicate the area where hand height is between eye height and 1/2 eye height.

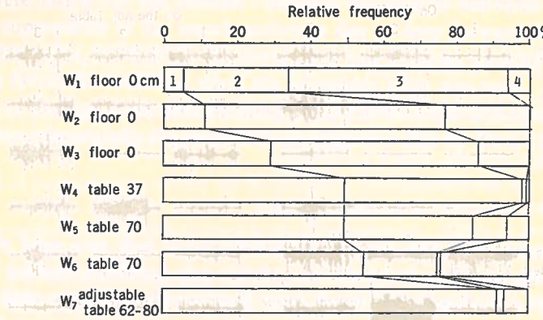

Fig. 3. Comparison of the relative frequency of working postures when work is performed on the floor level, at a table of fixed height, and at an adjustable table of optimul height. W_1–W_6, different workshops, work station height being indicated, W_7, experimentally simulated work using the adjustable table. 1, standing posture; 2, forward bending; 3, squatting; 4, others.

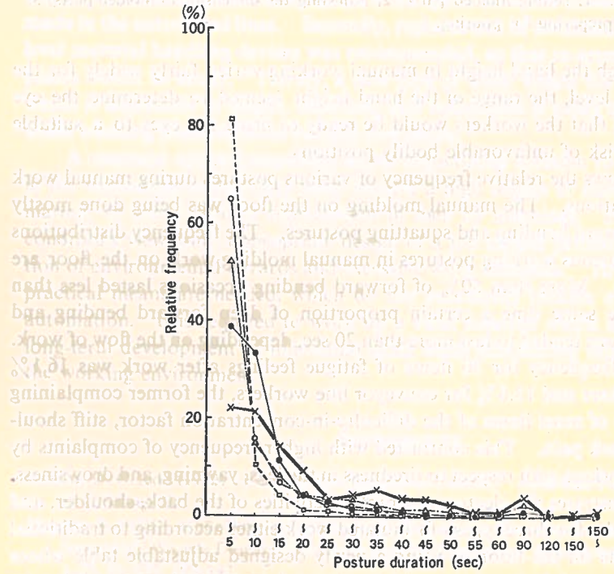

Fig. 4 Frequency distribution of duration of working postures during manual molding work on the floor. 1, standing posture; 2, slight forward bending; 3, deep forward bending; 4, forward bending with maximum inclination; 5, squatting. Observation time was 855 min. ●, 1; ○, 2; △, 4; ×, 5.

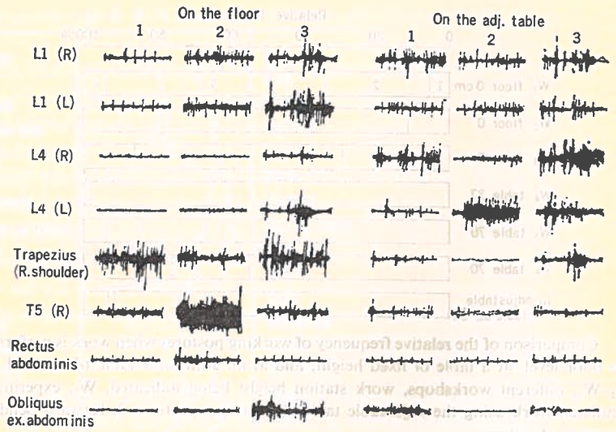

Fig. 5 Comparison of EMG patterns during simulated work on the floor and on the adjustable table. 1, setting molded parts; 2, adjusting the dimension of molded parts; 3, setting a jig preparing for pouring.

Fig. 2. Although the hand height in manual working varied fairly widely for the same eye height level, the range of the hand height seemed to determine the eye height, implying that the workers would be ready to bring the eyes to a suitable position at the risk of unfavorable bodily positions.

Figure 3 shows the relative frequency of various postures during manual work in different situations. The manual molding on the floor was being done mostly (70–90%) in forward bending and squatting postures. The frequency distributions of duration of various working postures in manual molding work on the floor are shown in Fig. 4. More than 50% of forward bending occasions lasted less than 5 sec, but at the same time a certain proportion of deep forward bending and squatting occasions tended to last more than 20 sec, depending on the flow of work.

The mean frequency for 30 items of fatigue feelings after work was 16.1% for manual workers and 13.6% for conveyor line workers, the former complaining more frequently of most items of the difficulty-in-concentration factor, stiff shoulders, and low back pain. This contrasted with higher frequency of complaints by conveyor line workers with respect to tiredness in the legs, yawning, and drowsiness.

Figure 5 illustrates the electromyographic activities of the back, shoulder, and abdominal muscles for three types of simulated work either according to traditional molding methods on the floor or using a newly designed adjustable table whose height, direction, and inclination could be changed to an optimal condition by means of operating a hydraulic system by foot-pedals. The activities of the back extension muscles at the L4 level were less for the traditional method than for work using the adjustable table, while those of the trapezius and at the thoracic

level were larger for the former. Because the smaller activities at the L4 level meant suppression of the muscle activities due to deep forward bending (Okada, 1972; Morioka, 1977), both the lower back and shoulder muscles proved to be in a more favorable condition when the adjustable table was used. The larger possibility of working in an erect standing posture at the adjustable table thus appeared to reduce substantially the workload, as suggested also by Zenz (1967, 1975).

DISCUSSION

We have seen that inappropriate work space and environment arrangements clearly present problems also relating to workload. This is also true for automated lines where poorly designed work space often results in a very high proportion of unnatural postures and intensified work which are specifically combined with constant exposure to dust, noise, and climatic stress.

As an engineering countermeasure to these ergonomic problems, I suggested re-arrangement of the workshops and the flow of processing in the plant, so that hazardous environment of pouring, core knocking, and others may not affect other workshops and considerations about work space with less noise and dust may be made in the automated lines. Secondly, replacement of overhead cranes by ground level material handling devices was recommended, so that re-arrangement of workplaces would be easier. Thirdly, a new type of work bench for manual molding which is adjustable in height, direction, and inclination is being developed so as to make working postures more natural and easier.

A common misunderstanding about ergonomics solution to human problems in the workshops is that they must involve a high degree of mechanization, automation, or some form of replacement of men by machines. From the working conditions viewpoint, appropriate design of a job should primarily involve reduction of environmental hazards and excessive work demands. To realize this, more practical means are needed, which do not necessarily include a higher degree of automation. It is required to work up a valid solution which is compatible with long-term development of individual skills while eliminating unhuman aspects of the working environment.

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