Chapter II

REVIEW OF RELATED LITERATURE

In the process of current research investigation, sincere attempt was made to broaden the spectrum of knowledge by going through the various sources of literature and acquainting oneself with various conclusions regarding the effect of physical fatigue on human performance, specially when one is actively engaged in movement. Some of the reviewed literature has been located underneath.

Vaid\(^1\) comparatively analysed the effects of mental fatigue on selected psychomotor components of sportsmen and sportswomen and she concluded that artificially induced mental fatigue significantly effected kinesthetic perception of sportswomen whereas in the case of sportsmen balance was negatively effected but two hand co-ordination improved significantly under the influence of mental fatigue. Sportsmen and sportswomen did not differ significantly on choosen psychomotor components if mental fatigue was not induced. But when induced sportswomen were found to be better in balance

\(^1\) Vinod Bala Vaid, "A Comparative Analysis of Effects of Mental Fatigue on Selected Psychomotor Components of Sportsmen and Sportswomen," (Unpublished Master's Thesis, Jiwaji University, 1987).
than sportsmen.

Brar\(^2\) investigated the psychophysiological performance variations of high and low fitness groups resulting from induced mental and physical fatigues. He concluded that:

1. Physical fatigue improved the reaction time whereas mental fatigue prolonged the reaction time, but fitness level and reaction time were independent.

2. Mental fatigue decreased the speed of movement whereas, physical fatigue did not affect it. Fitness and speed of movement were not related.

3. Mental fatigue and physical fatigue impaired the hand steadiness of the subjects.

4. Fitness was found to be an underlying factor of depth perception. Mental and physical fatigues impaired the depth perception.

Sprague and Mann\(^3\) filmed 15 males in the sagittal plane while performing a short (50 M.) maximal exertion sprint and a long (400 M.) fatiguing sprint. Kinematic and kinetic results were entered into statistical analysis. Initially quality of performance was significantly related to change in the kinetic variable of integrated muscle movement at each of the body joints. These variables were then logically related to changes in kinematic variables. The observations were made that better sprinter closely maintained the kinetic and kinematic patterns whereas the poorer sprinter inefficiently deviated in both areas and that the productive arm effort does not affect the level of performance in the fatigue condition.

Garcia\(^4\) assessed the maximum speed of forearm flexion, bio-electric co-ordination mechanisms and measures of maximum voluntary contractile force in the forearm flexors and extensors in twentyfour college aged men and women. All measures were collected under the normal inertial resistance condition and under two increased


inertial resistance conditions. Gender differences were observed in speed of forearm flexion, acceleration time etc.

Following agonist fatigue, significant increases in expressed movement time were observed. Following antagonist fatigue, decrease in expressed movement time were observed. These changes were discussed relative to gender, inertial load condition and type of imposed fatigue regimen.

Ewing\textsuperscript{5} determined the force-time characteristics of the grip-flexor muscle in 28 young adult women under four conditions - no fatigue and following fatigue equal to 80 per cent, 60 per cent and 40 per cent of maximal voluntary strength (MVC). The order of the four conditions was randomly assigned and consecutive sessions were separated by at least 48 hours. The mean of five trials under each condition was utilized in the analysis. During the fatigue trials the subject held a maximal isometric contraction until the strength had been degraded to either .80 MVC, .60 MVC, or .40 MVC at which

time the subject relaxed and within one second was
commanded to generate a contraction as rapidly and force-
fully as possible. Thirty seconds separated each of the
five trials. Forces were determine at 4, 8, 16, 32, 64, 128,
256, 512, and 1024 msec. The dependent variables analysed
were absolute force, normalized force, absolute
force velocity, normalized force velocity, time to reach
50 per cent of maximal force, and time to reach 70 per
cent of maximal force. The results of the analysis indicated
that as the fatigue level increased the absolute force
and absolute force velocity decreased. For normalized
force, fatiguing a muscle to 80 per cent of its maximal
strength was not different from the no fatigue level
except at 64 msec. where under the 80 per cent condition
a greater percentage of maximal force was attained. For
both absolute force velocity and normalised force velocity
the highest rates of tension uptake occured between 32
and 64 msec. under all conditions. The time required
to reach either 50 per cent or 70 per cent of maximal
force was not different between the no fatigue level and
.80 MVC fatigue level, but was significantly longer for
the .40 MVC level than for the remaining three conditions.
In addition, the time required to reach 70 per cent of
maximal force was greater for the .60 MVC than for the
.80 MVC fatigue level.
Kamen assessed fractionated knee extensor and planter flexor RT components in a group of 8 Weight Lifters and 8 Long Distance Runners. Following a 4-day period of baseline stabilization of each muscle group, a 50 per cent maximal voluntary contraction (MVC) holding time exercise was administered. Results showed that the runners had longer pre-motor times (PMT) than the Weight Lifters in the knee extensors, but had much faster PMTs than the Lifters in the planter flexor condition. Compared to previously reported investigation using non athletes, the data for the present sample of athlete indicated faster total RTs in both the knee extensors and the planter flexors. A resistance of 50 per cent MVC applied during the RT task resulted in a lengthening of the motor time (MT) component in both groups prior to exercise. However, while knee extensor resisted motor time was lengthened by the exercise task, no such lengthening occurred in planter flexor resisted RT. It is concluded that power-trained and endurance trained athletes exhibit differences in response to fractionated RT task, under both baseline and fatiguing exercise condition.

Johnson and Foster examined the effects of prolonged physical exertion on subjects' attitudes towards the task. The subjects peddled a bicycle ergometer at 50 cycles per minute for twenty minutes at one of the loads: 300 kpm min⁻¹, 600 kpm min⁻¹ or 900 kpm min⁻¹. While peddling they responded as quickly as possible to a stimulus tone introduced at random intervals throughout the twenty minutes period. Later, a questionnaire was administered to assess the subject's attitude towards the task. Subjects performing under heavy workloads perceived their performances to be poorer, felt more strongly that intermittent rest would have improved their performance whereas subjects performing under light loads found the task less challenging. Thus the study concluded that the levels of physical exertion experienced does influence subject's attitude towards the task.

Kearney and Stull tested fifteen college age males for maximum voluntary contraction (MVC) of the grip


flexors and were then subjected to five trials in which their strength levels were degraded to either 80%, 60% or 40% MVC. Immediately following the fatigue bout, the subject released his grip and upon command attempted to squeeze as rapidly and forcefully as possible. Testing was also administered under a non-fatigue state (1.00 MVC); every subject was tested under each condition with the order of administration assigned at random. The data were analysed based upon the amount of force generated at 4, 8, 16, 32, 64, 128, 256 and 512 ms. following the initial deflection from the base line. All values were normalized by dividing the force expressed by maximum force developed under that condition at 512 ms. The data analysis revealed that for each fatigue level the pattern of force uptake was sigmoidal; however, differences in normalized force were observed among fatigue levels of 64 and 128 ms. In general, at those time intervals there was an inverse relationship between fatigue level and expressed force. Analysis of the force velocities revealed that during the period from 8 to 64 ms. the rate of tension uptake was adversely affected as the level of fatigue was increased.
Anderson and associates\(^9\) fatigued both tibialis anterior muscles of twenty two subjects by means of isokinetic concentric or eccentric movement. Randomization determined which leg and mode of exercise would be used first. Electrical activity (EMG) was monitored with miniature bipolar surface Bechman electrodes placed over the muscles' mid-belly. A Howlett-Packard Fourier Analyzer determined the EMG frequency characteristics. Eight subjects consented to four muscle biopsies; a pre and post sample from each leg. The muscle tissue was fiber typed by adenosine triphosphatase (ATP) and succinate dehydrogenase (SDH). Analysis of variance corrected for separated measures and paired t-test were employed where appropriate with the 95% confidence level chosen for significance. Concentric or eccentric exercise, muscle contraction trials, and their interaction significantly decreased (\(F = 81.13\)) for fatigue. The EMG frequency characteristics of median frequency (\(F = 4.10\)), power spectral density function (\(F = 25.19\)), as well as mode of exercise significantly decreased. The muscle biopsies revealed a significant difference of type I over type II fibers for both legs with values of 63 to 37%.

for the left leg and values of 70 to 30% for the right leg. Under the test protocol, the tibialis anterior muscle was easily physically affected as demonstrated by the decreases in torque and EMG.

Barton\(^{10}\) investigated the effect of physical exertion on mental performance, as well as to look at this effect after various rest intervals. Specifically, the purpose of this study was to determine: 1) the effect of various levels of physical exertion upon mental performance of adult females; 2) the effect of physical exertion followed by various rest periods upon mental performance of adult females; and 3) if an interaction exists between intensities of exertion and length of rest periods.

Seventy-two college female students were randomly assigned to a control group or one of three groups varying in intensity of physical exertion: 110 beats/minute, 145 beats/minute, or 180 beats/minute. Each test session consisted of a pretest, a six-minute bicycle ergometer work bout, and from 2½ minute post-test scheduled 0, 5, 10 and 15 minutes after the exercise bout.

The mental test was the Brown and Poulton Test of Attention which requires each subject to audibly detect a sequence of digits which occurs in the order "odd-even-odd", and to respond by saying "yes" before the next digit is represented. The statistical tool for hypothesis testing was a 4x4 analysis of covariance with repeated measures on the interval factor.

It was concluded that:

i) Physical exertion of relatively short duration does not affect mental performance of adult females. Therefore, mental performance following various intensity of physical exertion does not follow the inverted-U hypothesis.

ii) While mental performance across various rest intervals changes, these changes may not be a distinct function of physical exertion.

iii) Groups of adult females exercised at different exertion intensities exhibit similar mental performance across various rest intervals.
Johnson examined the effects of various levels of fatigue on recognition memory with the help of thirty-six subjects. The subjects, who were required to learn certain items, were divided into two groups based on memory set size. The memory set items consisted of dot patterns of the Garner-Clement vaicity. These memory set items as well as alternates (items never seen by the subjects) were presented via Tachistoscopic Slide Projector. The items were of five types: 1) Target items of high goodness, 2) Target items of low goodness, 3) alternate items of high similarity to target items of high goodness, 4) alternate items of high similarity to target items of low goodness, and, 5) alternate items of low similarity to both types of target items. Upon presentation of each item a digital response time counter would begin to register. The subjects responded to each item by depressing a telegraph key which stopped the response time counter. Correctness of response as well as response times were recorded for each item. All subjects completed the above procedure under the influence of fatigue induced by pedaling a cycle ergometer.

Fatigue levels were no fatigue, 80% of $PWC_{170}$ for six minutes, and 100% of $PWC_{170}$ for six minutes. The subjects responded to each item presentation concurrent with pedaling of the cycle ergometer.

The results indicated that fatigue of the type and intensity employed does not significantly effect overall recognition time. There was, though, a significant difference in response times between the target items of highgoodness items showing the better response times. Among the lures, the lure which was dis-similar to both target items had the fastest response time.

Regression analysis was used to fractionate memory into component stages. An arousal effect in the form of an inverted U was noted in the comparison stage of memory. It was also noted that an intermediate level of fatigue hindered performance in other stages of memory. The fact that opposite effects were revealed in these stages of memory may have contributed to the fact that no overall effects on recognition time were shown.

Sayah\textsuperscript{12} tested Thirty College males on simple

\textsuperscript{12}Sayah, Completed Research in Health, Physical Education and Recreation : 88.
reaction time, movement time, and response time on a task which involved jumping forward upon initiation of a visual stimulus at a distance of 50 cms. The fatiguing task involved an arm ergometer exercise consisting of 3 minute stages beginning at 0 kpm/minute, progressively increasing by 150 kpm/minute until the subject maintained a 180 heart rate for 15 seconds. Practice and warm-up trials were given to control learning and warm-up decrement factors. The pre-test consisted of 4 trials with 15 seconds intervals between trials. After the arm exercise, the subject was given a 1 minute rest prior to post-test, after which, there was a 3 minute rest before the recovery 1 test. Recovery 1, 2, and 3 tests were interspaced by 3 minute rest intervals while the 4 trials within treatments were interspaced by 15 seconds rest intervals. ANOVA with repeated measures indicated (P < .01) that RT, MT and Response Time were significantly faster during the pre-test than during post-test and recovery. It was concluded that the upper extremities fatigue caused decrement in performance of the lower extremities.
Kamen\textsuperscript{13} investigated the source of peripheral delay in a volitional response task by extending the fractionated reaction time paradigm to include two previously undefined components. One component, termed mechanical latency (ML), was defined as the interval between the initial deflection of the muscle action potential and the first observable rise in the tension trace. The second component, termed tension development time (TDT), was defined as the time needed for the subject to generate a small fraction (15\%) of his maximal voluntary contractile force (MVC). Reasons were forwarded for the belief that TDT is likely representative of the motor unit recruitment characteristics of the muscle.

An attempt was also made to describe the force-time characteristics of the planter flexors during a maximal contraction performed under ballistic conditions. Unexpected changes in the shape of the force-time curve were observed across the six test days, and these changes were considered to be a part of the "learning" response necessary to elicit a maximal contraction. Four exercise

regimens were administered to each of the twelve subjects. The factor of contraction type was investigated by using both rhythmic isotonic contractions as well as an isometric holding-time task, while the factor of contraction intensity was studied by using either high-intensity (50% MVC) or lower intensity (25% MVC) contraction. Each subject performed each exercise twice (once using each of the two muscle groups), so that a total of eight exercise session were administered.

Similar decrements in MVC were observed across all four exercise conditions and for both muscle groups. Analysis of the volitional response and reaction time measures revealed little change under normal, unrestricted condition following fatiguing exercise. The addition of an increased resistance to the knee extensor RT task lengthened total reaction time, particularly the peripheral motor time component. The changes in peripheral motor time were pronounced following exercise. However, analysis of the planter flexion RT task revealed no changes in any of the fractionated RT components under resisted condition.

Changes in the force-time characteristics of the fast maximal planter flexion contraction after
fatiguing exercise mirrored the decrements which occurred in MVC. Rates of tension development were lower after exercise, while the time needed to reach any given absolute level of tension was longer. After fatiguing exercise, a lengthening of the motor time component of the patellar tendon reflex was observed, while several components of the Achilles tendon reflex manifested in a facilitated response. A comprehensive hypothesis, which considered differences in morphological and contractile characteristics of the planter flexors and knee extensors, was forwarded to account for the difference in response of the two muscle groups to fatiguing exercise.

Gabbard¹⁴ analysed the effects of induced physical exertion on the performance of an immediate mathematical mental ability task among second-grade students (physical exertion for 20, 30, 40, and 50 minutes). Another purpose was to determine whether males or females were more affected by experimentally induced treatments of physical exertion. The study involved 106 second-grade students selected from the same school. Experimental

treatments were induced during regular physical education classes and the movement activities performed during the physical exertion sessions were specific relay game activities that were performed in a continuous cycle as the duration of the sessions got longer.

The students were assigned six mathematical mental ability tasks. Four of the tasks were performed 5 minutes after the completion of each of the four physical exertion session. The first (pre-test) and the six mental task session were performed without induced physical exertion and the comparison between them served as the study control. Each mental ability task was composed of thirty six first grade level problems that required adding and subtracting with no borrowing a carrying functions. The students were given two minutes to complete each of the six mental tasks. The mathematical task scores served as the dependent variables and were statistically analysed. A one-way analysis of variance for repeated measures was used to test for significant differences among the six experimental treatments. The Dunnet Multiple Comparison Test was utilized to determine which treatment means differed significantly when a significant F-ratio was found. The .05 level of significance was the level at which six hypothesis were either
accepted or rejected. The one-way analysis of variance with the mean difference option was utilized to compare male and female mean difference performance, when the one-way analysis of variance revealed significant differences. The post hoc test revealed that the only significant difference when comparing the pre-test to the five post-test was the fifty minute treatments. Males and Females did not differ significantly on this performance.

It was concluded that 50 minutes of prolonged physical exertion as induced had a positive effect on certain mathematical tasks. Another conclusion derived, was that physical exertion periods of 20, 30 and 40 minutes had no significant effect on certain mental performance when compared to a non-induced physical exertion treatment. It was also concluded that there was no significant differences between male and female mean difference performances.

Singh\textsuperscript{15} assessed the effects of four levels of stress on signal detection performance between active and sedentary individuals. In addition the relationship of heart rate levels and $O_2$ consumption on signal detection

\textsuperscript{15}Singh, Dissertation Abstracts International: 4028.
was also investigated. Eight male subjects between 18 and 25 years of age were subjects in this study. Four subjects were assigned to an active group and four subjects to a sedentary group determined by establishment of specific criteria. Subjects were individually evaluated on tests of maximum aerobic capacity and signal detection performance. Both groups of subjects were given a walking treadmill test of graded intensity to determine the $O_2$ consumption and heart rate for the three levels of applied stress. The treadmill was elevated at regular intervals until the third stress level elicited a heart rate greater than 155 bpm. $O_2$ samples were taken at the lower and upper limits of each three different heart rate levels. The second part of the experiment consisted of eliciting four levels of stress as determined by the first part of the test at which signal detection performance was measured. To confirm the reproductibility of the walking maximum $O_2$ consumption, the subjects were tested by an all-out treadmill run with the measured $O_2$ consumption being satisfactorily similar in value. A three-way (4x2x3) ANOVA was used to ascertain the difference of means of the independent variable. The analysis indicated that heart rate and stimulus contrasts affected the sensitivity of the
subjects. A second four-way (4x2x3x3) ANOVA was conducted to ascertain the difference of means of the "Z" measures. The analysis showed that heart rate and contrasts affected the decision of the subjects. Comparison of walking $\bar{V}O_2$, running maximal $\bar{V}O_2$ revealed similar values. Within limits of this study it could be concluded that increasing levels of stress caused decrements in signal detection performance. There was no difference between active and sedentary individuals on signal detection performance. A relationship did exist between heart rate and signal detection performance.

Morris$^{16}$ examined fractionated reflex responses after local fatiguing isotonic and isometric muscular exercise of the quadriceps musculature. The fractionation procedure enables one to subdivide total reflex time into peripheral and central components. The central component (reflex latency) constitutes the time for the monosynaptic reflex arc. The peripheral component (reflex motor time) represents the time for muscular

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contraction. Twelve male university students were tested prior to and after severe isometric and isotonic exercise. Isometric exercise produced a strength decrement of 57%. The isotonic exercise task produced strength decreases of 35%. Although differential strength decrements were shown, both exercise types significantly (p < .01) lengthened total reflex time. Additionally, both reflex latency and reflex motor time were increased. These results suggest that severe muscular fatigue of either isometric or isotonic origin adversely affects total reflex time, especially the peripheral (muscular) component.

Bates and Ostering\textsuperscript{17} studied the effects of fatigue on 12 female subjects who were filmed at two stages of a maximal effort, gross physical performance task (running). Comparisons were then made between selected temporal and kinematic parameters describing the activity. The results appear to support the concept that fatigue does not simply produce a uniform reduction in the components of a movement pattern but, rather, changes their relationship completely.

Sims\(^{18}\) analysed the influence of different mental tasks upon the heart rate of the college males while running. The treadmill was selected as the medium for running using a ten percent grade at two miles per hour for one minute and five miles per hour for five minutes with the heart rate recorded every minute. Heart rates were measured by a Cardio-techometer.

Eighty college age males acted as subjects for this study. The subjects were randomly assigned to one of the four experimental groups of twenty each. Group I was assigned a simple mental task. Group II was assigned a difficult mental task. Group III was assigned a free association mental task. Group IV served as a control group. The three experimental groups ran on the treadmill twice; during one session with the mental distractor and once without a mental distractor. The control group ran both sessions without a mental distractor. The simple mental task consisted of short simple questions taking approximately 4 second to answer. The questions were projected one at a time, by the use of

an overhead projector. The difficult mental task consisted of questions which took about 10 seconds for a subject to answer. The free association mental task was performed with the investigator orally supplying one word "clues" upon which the subject concentrated on as many associable things as possible. When the subject could no longer concentrate on associable things another word was supplied.

A factorial analysis variance with a split-plot design was utilized to determine whether a significant difference existed between scores recorded at one, two, three, four, five and six minute intervals of the four groups, using two trials, one with and one without distraction. Factorial analysis was also utilised to determine whether a significant difference existed between heart rate recordings taken after six minutes of exercising between the two trials, one with and one without distraction. It was concluded that during exercise the heart rate could be influenced by the mental process. Simple or free association mental distraction will reduce the increase in heart rate during exercise. It was also concluded that difficult mental distraction would incres the heart rate during exercise. The effectiveness of mental distraction on heart rate while exercising seemed greater as the exercise progressed.
Stockard\textsuperscript{19} determined if practicing novel gross motor task under a specific condition of physical fatigue would influence either the learning that resulted from practice or the subsequent performance of the task. Three experimental groups practiced a novel gross motor task under three different levels of physical fatigue. The conclusion reached was that in vigorous sports where physical fatigue is a factor, practice may best be held under conditions of physical fatigue which simulate actual game conditions.

Cotten and associates\textsuperscript{20} determined the effects of interpolated specific and total body physical fatigue upon the performance and learning of a gross motor skill. Seventy-five male subjects were randomly assigned to one of three groups: Group A (specific body fatigue), Group B (total body fatigue), and Group C (control). The gross motor learning task was a modification of Mirror Target Toss Test (Mc Grow). Each subject was given one initial trial (5 throws). This was followed by the appropriate experimental condition: Group A - 7 minutes of severe


overall physical activity (stool stepping - 60 complete step-ups per minute), Group B - 5 minutes of severe specific exercise (reverse curling 23 lb. Easy curl bar - 30 rep. per minute), and Group C - 5 minutes of rest. Each subject was then given 10 consecutive trials (50 throws) with the assigned physical fatigue interposed for 30 seconds following each 2 trials. On the subsequent day, the subjects were given 3 consecutive trials (no exercise condition on second day). The learning score was calculated by the percent of possible improvement method:

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\text{Learning} = \frac{\text{Final Score} - \text{Initial Score}}{\text{Max. Possible Score} - \text{Initial Score}}
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The score of the first trial served as the initial score while the \( \bar{x} \) of the 3 trials for the second day served as the final score. The reliabilities for the learning tasks for each group were \( r_A = .89, r_B = .83 \) and \( r_C = .90 \). The learning scores for each group were analyzed by simple ANOVA with the results indicating that fatigue had no significant effects upon the amount learned. The effects of either total body or specific fatigue upon performance curves were analyzed by Discriminant Analysis. Results indicated that the curve of the group resting before and between trials was significantly different from the curves of the other two groups.
The results of this study indicated that while performance was impaired by both specific and total body fatigue, the amount learned was unaffected by fatigue.

Burke\textsuperscript{21} examined the effect of different levels of physical exertion, as measured by heart rate on dynamic balance (DB). A Latin Square arrangement was used to assign the levels of exertion: rest, light (120 bpm), medium (140 bpm), heavy (160 bpm), and severe (180 bpm), to each of the 12 subjects. A modification of Reynolds' Balance Device (RBD) was used as the instrument to measure DB performance. Each subject first rode the bicycle ergometer for seven minutes and then took six trials at one minute intervals on the RBD. A trial consisted of the elapsed time from the onset of the first stimulus light to the completed response of the fifth stimulus light. The fastest DB scores were achieved immediately after light and medium levels of exertion. Slower DB scores were achieved on trials two, three, and four after heavy and

severe levels of exertion. Consequently it seems that prior physical exertion at 120 bpm and 140 bpm tends to enhance the DB performance on the RBD. In contrast, prior exertion at 160 bpm and 180 bpm tends to induce slower DB scores up to five minutes after performance on the bicycle ergometer.

Simpson\textsuperscript{22} compared the $O_2$ uptake, heart rate and RQ recovery curves of high-average and low-average fitness subjects, after high intensity—short duration and low intensity—long duration treadmill work bouts. A secondary purpose was to investigate the relationship between the heart rate, $O_2$ uptake, and RQ recovery curves of the high-average and low-average fitness groups after the two work bouts.

The subjects were 30 male college students. Two groups of 15 subjects each, one representing high-average CV fitness and one exhibiting low-average CV fitness, were selected on the basis of the Harvard Step Test (short form). Two treadmill work bouts were established for both

groups: a high-intensity run of one minute duration and a long-duration walk of 15 minutes, with progressive increases in elevation. The criterion for the termination of each work bout was a heart rate level of approximately 180 bpm. Recovery heart rate, and $O_2$ samples were taken during the first, sixth, eleventh and sixteenth minute of the recovery period. The statistical matrix utilized in this study consisted of a three-factor analysis of variance with a nested factor. The three factors consisted of fitness categories, exercise time and recovery pattern. Comparisons were made of the three recovery patterns at the four levels outlined to determine whether or not significant differences existed between the high-average and low average fitness subjects after both work bouts.

It was concluded that the heart rate, $O_2$ uptake and RQ recovery patterns of high fitness and low fitness subjects varied according to the intensity of the work bout used to achieve the 180 heart rate. There was a high relationship between heart rate, $O_2$ uptake and RQ after the cessation of exercise as indication of CV condition. A work bout that produced a heart rate of 180 within one minute resulted in a higher heart rate, greater $O_2$ uptake and higher RQ during the recovery period after the cessation of exercise than a work bout in which the criterion heart rate was reached after 15 minutes of
exercises.

Flynn selected 9 to 11 year old subjects with varying aerobic capacity (AC) levels to study the effect of varied intensities of physical exertion on numerical task performance. The subjects were divided into three groups according to relative aerobic capacity levels as determined by performance on a sub-maximal work test on a bicycle ergometer. The 10 subjects with the lowest heart rates during the test comprised the high AC group, the 10 subjects with the next highest heart rate comprised the moderate AC group, and the other 10 subjects with the highest heart rates comprised the low AC group. All the subjects were then tested individually on five different days. Each formal testing session consisted of a 3-minute rest period while the subject was seated on the bicycle ergometer, followed immediately by a 6-minute bout of physical exertion (rest, 0, 150, 300, or 600 km/min) followed immediately by a 3-minute numerical task. The numerical task consisted of problems containing three digits to add and/or subtract, i.e. 8-5+3 = ___.

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Both accuracy score and speed score were recorded and later analyzed. Heart Rate was recorded following each minute of rest, during each minute of physical exertion, and following each minute of the numerical task. Numerical speed and accuracy, and heart rate data were analyzed in separate three-way analysis of variance, AC (3) x exertion (5) x minutes (3) of the numerical task after which post hoc comparisons were made utilizing Duncan's Range Test. For heart rate, as expected, significant F ratios were obtained for main effects on exertion levels and recording periods, and also on the exertion x multiple interaction. A positive linear relationship was found to exist between exertion level and heart rate. Significant differences were also observed between heart rates attained by high AC and low AC groups during the three highest level of exertion with lower heart rates recorded for the high AC group. Numerical task performance was not found to be significantly affected by the five intensities of physical exertion, and numerical task performance did not significantly differ for the three AC groups. For numerical speed, a significant F ratio was found for the main effects on minutes. Further analysis indicated that speed score was significantly lower during minute three than during minute one following the two highest levels of exertion. The results of this study
failed to provide evidence that prior exertion has an effect on arithmetic accuracy performance in children 9 to 11 years old.

Bryant\textsuperscript{24} filmed five basketball players of University level. He filmed 16 mm., 64 f.p.s., 3 synchronous views, lower, upper and full body for a mechanical and cinematographic analysis through a descriptive case study approached of the motor skill of the basketball jump shot and the effect of fatigue on the jump shot. Subjects performed 3 sets of 10 shots from 20 ft. in front of the basket, the first following minimal exertion and the second and third after 30 minute controlled basketball scrimmages, with a 109 ft. sprint preceding each jump shot. A composite of the jump shot was developed representing ranges of selected body measurements and application of mechanical principles and laws. Jump shot performance and effect of fatigue were found to be individualized. Six body measurements were found to be affected by fatigue between sets and 4 within sets. The variation of the jump shot did not reveal the mechanical reason for long range shooting skill on the basis of playing background. Superior

shooters used a continuous style and the long levered play may have an advantage from 20 ft. in front of the basket.

Schwartz\(^{25}\) placed thirty male college subjects in two groups to discover if varying degrees of general muscular fatigue had any effect on depth perception. The experimental group pedalled a bicycle ergometer under conditions of increasing work loads until a heart rate of 170 bpm. was reached, or until unable to pedal was required. The depth perception scores and heart rate were recorded simultaneously at pre-selected times during the experimental period. All the subjects in the experimental group were actively exercising during the time these data were collected. The data from the control group were collected following the same procedure concept that they did not perform any physical work. ANOVA indicated no significant differences between the depth perception scores of the experimental and control group; no significant changes occurred in depth perception scores during the experimental period, and no significant interaction effect. These findings were confirmed by the paired 't' test that indicated no significant differences between initial and final depth perception scores of either group.

Richard investigated the status of physical fatigue as a variable affecting performance and/or learning of a grass motor skill. Three groups practiced ten 30-sec. trials on the Bachman ladder with a 90-sec. intertrial interval (Day 1). Two fatigue groups rode a bicycle ergometer for two minutes prior to trial 1, and thereafter, for 75 sec. between each subsequential ladder trial work loads of 750 (N=13) and 1200 (N=14) Kgm/mm. respectively. A control group (N=20) cancelled vowels between trials. All groups returned two days later (Day 2) for four trials with intertrial rest, the mean of which was the criterion of amount learned. Fatiguing activity caused decrements in Day 1 performance ($F=3.32$), but failed to affect Day 2 performance ($F=0.47$), indicating that fatigue was a performance variable rather than a learning variable.

Lockey was keen to test 22 subjects on speed of movement of the lower extremities. The control group relaxed in a chair before they were tested. Subjects of experimental group rode a bicycle ergometer until the Heart Rate of 180 bpm. was reached. It was found that the


speed of movement increased as a result of that amount of fatigue.

Eighty Junior High School Boys were divided into two groups by Marshall. The experimental group undertook a 10-minute step-up exercise just prior to performing on a stabilometer, while the control group performed on the stabilometer without a fatigue bout. There was a significant decrement initial, final and overall performance for the experimental subjects, which supported the hypothesis that preliminary unrelated fatiguing exercise would cause a detrimental effect on performance. However, no alteration in the rate of learning was found.

Albert attempted to know the effects of physical fatigue upon the learning of a motor skill, 75 college women were assigned in systematic rotation to either a control group or to one of the two experimental groups. All subjects were given a total of 50 trials on the pursuit rotor: 25 trials on Day I, the practice session; and

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28 Marshall, Completed Research in Health, Physical Education and Recreation : 139.

29 Albert, Research Quarterly : 682.
25 trials on Day II, the test session. One of the experimental groups was fatigued early in the practice session while the other was fatigued late in the practice session. Fatigue interpolated early and late was detrimental to subsequent performance improvements but had no effect upon the amount learned.

Kendrick tested five groups of college men on one of the following grass motor skills: Basketball free throws, Basketball jump shots, repeated vertical jumps, total body response, accuracy, and 20-yards sprints. Subjects were then given a submaximal work bout consisting of bench stepping at 33 steps/minute until the established criteria for fatigue were reached. It was found that general body fatigue impaired performances which called for strength, endurance, and rapidity of response. Accuracy performance using a light object, as in Basketball shooting, was not appreciably affected by general body fatigue. Five minutes of rest was not sufficient to recover from fatigue in tasks involving repeated jumps and repeated short sprints.

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Four groups of subjects were constituted and assigned either to the rho motor learning test (speed) or the pursuit rotor motor learning test (accuracy) by Alderman\textsuperscript{31} under either control or experimental conditions. Practice on each task lasted approximately 30 minutes and resulted in large amounts of learning. Interpolated severe local physical fatigue was induced by exercising the experimental groups on an arm ergometer halfway through the learning of each task. The experimental groups suffered a 40 per cent decrement in performance as a result of the interpolated fatigue, but the amount of learning was not influenced.

Phillips\textsuperscript{32} found that the related warm-up exercise of moderate intensity failed to improve arm speed in a large muscle criterion movement, while heavy but non related exercise did improve the speed by 16 per-cent. Three groups, each consisting of 25 male college students, were measured under both test and control conditions.


Neither of the warm-up exercises influenced reaction latency. The correlation between reaction time and movement time scores was non-significant. For the heavy exercise (stool-stepping), highly reliable individual differences were observed in stepping rate drop-off before fatigue and after 37 percent fatigue, but the two types of drop-off scores were not significantly correlated. In the arm action warm-up exercise, the correlation between initial rate of movement and rate at 24 percent fatigue was non-significant.

Rich33 obtained exponential fatigue curve for dynamic work of forearm muscles from 200 boys and girls ranging from 8 through 17 years of age. The fatigue parameters analysed in relation to initial strength were fatiguable strength, steady state equilibrium strength, and relative rate of strength loss per contraction. Older children were stronger and exhibited greater fatigue. When their strength loss and steady state levels were considered in relation to their initial strength capacity, there were no age differences in fatiguability and sex differences were either absent or very small. Older boys,

since they exerted more strength initially, tended to reach fatigue level more rapidly than younger children. Older girls reached their fatigue level more slowly.

Antero-posterior and lateral postural deviations of high school girls were rated by five experienced judges on the basis of silhouettes in an investigation conducted by Mc Tarsney.\(^{34}\) Scales were constructed to assist in rating. Fatigue was evaluated by a questionnaire constructed to attempt to measure both current and chronic fatigue states. Static and dynamic balance were measured by the Balance on Stick and Sideward Leap Tests. On the basis of the judges rating of the silhouettes, four groups were differentiated. No relationship was found between balance and fatigue. The normal antero-posterior posture group showed a greater fatigue rating than the deviate antero-posterior group. The normal antero-posterior, deviate lateral posture group showed greater fatigue than the deviate antero-posterior, normal lateral posture group.

Lotter\textsuperscript{35} stated that other studies have shown that a three component exponential fatigue curve can be used to compute speed as a function of elapsed time in running. The present investigation shows that this type of curve describes accurately the initial build-up in rate of arm-shoulder movements and subsequent drop-off from fatigue in a four minutes test and retest of twenty college men. Warm-up preceding one of the tests is found to have no influence. One test period causes a practice effect of 2.7 percent, chiefly in the first third of the curve. Test-retest reliability is low ($r = .51$) for the first five seconds of performance. For each third of the total test it is fairly high, ranging from .82 to .87.

Elbel\textsuperscript{36} determined the effects of various forms of strenuous exercise upon the response time of men. The response was measured by determining the interval elapsing between the sound of a bell and the movement of various parts of the body. The drawn conclusions were that: no significant change in finger response time; Hand and


body response time - no significant change in the case of stool-stepping and push ups but it was shortened by athletic competition; Hand Speed Accuracy - athletic competition caused significant improvement in one group and a decided improvement in the other; and Fencing Time - Accuracy - definite periods of fencing led to improvement.