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Research article

THE IMPACT OF MODERATE AND HIGH INTENSITY TOTAL BODY FATIGUE ON PASSING ACCURACY IN EXPERT AND NOVICE BASKETBALL PLAYERS

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ABSTRACT

Despite the acknowledged importance of fatigue on performance in sport, ecologically sound studies investigating fatigue and its effects on sport-specific skills are surprisingly rare. The aim of this study was to investigate the effect of moderate and high intensity total body fatigue on passing accuracy in expert and novice basketball players. Ten novice basketball players (age: 23.30 ± 1.05 yrs) and ten expert basketball players (age: 22.50 ± 0.41 yrs) volunteered to participate in the study. Both groups performed the modified AAHPERD Basketball Passing Test under three different testing conditions: rest, moderate intensity and high intensity total body fatigue. Fatigue intensity was established using a percentage of the maximal number of squat thrusts performed by the participant in one minute. ANOVA with repeated measures revealed a significant ($F_{2,36} = 5.252$, $p = 0.01$) level of fatigue by level of skill interaction. On examination of the mean scores it is clear that following high intensity total body fatigue there is a significant detriment in the passing performance of both novice and expert basketball players when compared to their resting scores. Fundamentally however, the detrimental impact of fatigue on passing performance is not as steep in the expert players compared to the novice players. The results suggest that expert or skilled players are better able to cope with both moderate and high intensity fatigue conditions and maintain a higher level of performance when compared to novice players. The findings of this research therefore, suggest the need for trainers and conditioning coaches in basketball to include moderate, but particularly high intensity exercise into their skills sessions. This specific training may enable players at all levels of the game to better cope with the demands of the game on court and maintain a higher standard of play.

KEY WORDS: Squat thrusts, ecological validity, anaerobic.

INTRODUCTION

Fatigue is a very complex conception, involving both psychological and a host of physiological factors (Astrand and Rodahl, 2003). Consequently, fatigue should never be viewed as a single entity or process. Rather it is a highly complex phenomenon, comprising numerous different components and acting at multiple sites within both the central nervous system and the muscle (McKenna, 2003). Fatigue is especially important in a sporting context and in a team game such as basketball, fatigue may be the determining factor between winning and losing. The study of fatigue relative to performance of different skills has long been a subject of practical and scientific interest to strength and conditioning professionals, trainers, coaches and sport scientists. Research to date however, has provided conflicting and often contradictory findings partly due to inconsistent experimental designs and procedures used. Anshel and Novak (1989) partly attribute the conflicting results to poor control of the participant's fitness and/or strength levels and the intensity of administered fatigue. This picture is made even more complex by the fact that fatigue is difficult to define.

Previous investigations examining the effect of fatigue on performance in basketball are very scant indeed. However, Ivoilov et al. (1981) did examine the effects of a two versus two game of basketball on shooting performance and found that basketball-shooting accuracy deteriorated significantly following the fatigue protocol. Legros et al. (1992) examined the effect of treadmill running at 95% and 125% of VO_2max on simple and choice reaction time in expert basketball players. Their results showed an impairment in simple reaction time under exertion. Though choice reaction time improved, there was an increase however, in error rate. In other sports such as soccer, McMorris et al. (1994) examined passing performance following rest, exercise at 70% and 100% of maximum power output. Results showed that for total points scored, performance following exercise at 70% maximum power output was significantly ($p < 0.01$) better than in the other two conditions, which did not differ significantly. The distinct lack of empirical work on this topic however, together with the fact that less attention has been paid to the fatigue effects in expert and novice players suggests that further research is warranted.

Currently, there is a plethora of literature relating to expert-novice differences across a wide range of sports and research topics. Clearly evident from this literature is that there are critical characteristics and underlying differences that separate expert and novice players in sport. Experts have demonstrated more effective anticipation than novices (Farrow and Abernethy, 2002; Shim et al., 2005), better perceptual-cognitive skills (Kioumourtzoglou et al., 1998; Ripoll and Latiri 1997; Ward and Williams 2003), better decision-making and tactical expertise (Nielsen and McPherson, 2001), better technical expertise among other factors. In basketball, the above characteristics are fundamental in discriminating between expert and novice players (Lyoka and Bressan, 2003). It is these characteristics therefore, together with a high degree of sensorimotor integration that allow expert basketball players to perform the requisite skills with movement patterns that are refined, efficient and almost automatic.

Intuitively, it would appear that because experts possess these superior performance characteristics, that they must also be capable of dealing with affective states more appropriately than novices (Janelle and Hillman, 2003). A number of underlying theories have been put forward in previous work attempting to explain expert-novice differences. One such theory is that experts are capable of regulating emotional fluctuations with compensatory mechanisms to allow the maintenance of high performance levels (Janelle and Hillman, 2003). Whether experts are also capable of using compensatory mechanisms to maintain high performance levels under fatigue conditions is unclear however, and will be the focus of this work. Theoretically, Cooper (1973) highlighted that exercise (or fatigue in the case of this research) induces physiological and biochemical changes that are similar to those found when arousal increases. He pointed out that during exercise there are increases in heart rate, respiratory rate, blood pressure, sweating as well as increases in CNS levels of catecholamines, adrenaline, and noradrenaline all of which are thought to be indicative of increases in arousal (Lacey and Lacey, 1970; Sothman et al., 1991). More recently however, some researchers have argued that this relationship needs to be better explained than simply pointing to similarities in the physiologic symptoms shown by both types of arousal (McMorris et al., 1999). Despite this, many different theories have developed over the last century attempting to explain the relationship between exercise, arousal and performance. The most relevant ones to this research are summarised here.

One of the earliest theories is the Yerkes and Dodson (1908) Inverted-U Theory, which was later reformulated in terms of underlying attentional mechanisms. Easterbrooks (1959) Cue Utilisation Theory put forward that variations in arousal would produce a change in attentional processes. According to cue utilisation theory, when arousal is low attention is focussed on both relevant and irrelevant cues and thus, performance remains poor. As arousal rises however, to a moderate level (top of the inverted U) attention narrows onto task-relevant cues only and performance is optimal. If arousal continues to rise to a high level attention will narrow further and even relevant cues will be missed; therefore, performance returns to baseline.

Following the Yerkes and Dodson (1908) Theory, Drive Theory was derived from the work of Hull (1943) and later modified by Spence and Spence (1966). This theory argued that performance (P) is a multiplicative function of habit (H) and drive (D): $P = H \times D$. Hull saw drive as physiological arousal and habit as the dominance of correct or incorrect responses. Simply stated, Drive Theory put forward that there is a positive relationship between arousal and performance. Furthermore, increases in arousal should enhance the probability of making the dominant response. Consequently, as a skill becomes well learned increases in arousal facilitate performance. A similar view was put forward by Oxendine (1984) who argued that gross motor activities involving strength and speed, which are typically over-learned have habit patterns that are strongly formed. As a result of this strong habit pattern a very high level of arousal is desirable for optimal performance.

The theories cited so far perceived arousal as being unidimensional in nature and have been criticised as being too simplistic with some authors questioning whether arousal is in fact unidimensional (Jones 1990). As a result more recently, researchers (Delignieres et al., 1994; McMorris and Graydon, 1997) have drawn on multidimensional, allocatable theories as the theoretical rationale for their work. The first of these was put forward by Kahneman (1973), who introduced the notion that performance is affected by arousal and what he termed cognitive effort. Arousal refers to the amount of resources available to the central nervous system (CNS), whereas effort is responsible for the allocation of these resources. This theory hypothesises that performance at low arousal or rest can be optimal if cognitive effort can allocate sufficient resources to the task. Performance at high intensity however, will deteriorate, as cognitive effort cannot focus attention solely on task-relevant information. Kahneman, (1973) referred to this latter effect as increased distractibility. High levels of arousal can cause the individual to direct attention to many different sources, some of which provide irrelevant information and cause relevant signals to be missed. An example of this, when exercise is the stressor would be the inability to ignore perceptions of pain, distress or fatigue (McMorris and Keen, 1994; Salmela and Ndoye, 1986).

In terms of fatigue, according to Szgula et al. (2003) there are two different patterns. Firstly, the pattern being the effect of short-term effort of high-intensity and secondly, the pattern as a result of long-term exercise. To date, anaerobic type work has not been used much to induce fatigue in studies examining the effect of fatigue on performance of sports skills. In most situations, fatigue has been assessed in static contractions, engaging a restricted group of muscles acting on one single joint (Jones et al., 2004; Lewis and Fulco, 1998) and hence the application of findings to sporting situations is limited. It is also evident from the literature that little attention has been paid to the evaluation of fatigue in the field setting during dynamic contractions involving larger groups of muscles (Astrand and Rodahl, 2003; Lewis and Fulco, 1998).

The design of the current research and more specifically, the fatiguing task was chosen for a number of methodological and theoretical reasons. Firstly, the fatiguing task considers the previous points raised by Astrand and Rodahl (2003) and Lewis and Fulco (1998). Secondly, it is widely acknowledged that in basketball there is a considerable anaerobic element to the game (Crisafulli et al., 2002; Hoffman 2002; McInnes et al., 1995). Arnett et al. (2000) also believe that the fatigue experienced during games is predominantly the result of anaerobic-type work and as such an anaerobic fatiguing task (rather than an aerobic task) was more reflective of the fatigue experienced during games. The fatiguing task utilised in this study is very much anaerobic in nature. Thirdly, Anshel and Novak (1989) highlight that in some previous studies the use of general fatigue as opposed to fatiguing the specific muscles used in the criterion task is a methodological limitation. McMorris et al. (1994) add that it is possible that fatigue only affects performance if the muscle groups fatigued are the same ones being used in the criterion task. In the present research the fatiguing task impacted heavily on the muscle groups also utilised in the passing test.

Basketball is a game of continuously changing tempo, requiring speed, acceleration, explosive movements such as rebounding, driving lay-ups, jump shooting, shot blocking, fast breaks and high-speed play. The game also involves skills that must be applied dynamically, explosively and repeatedly (Gore, 2000). According to Hoffman et al. (1995) high intensity, moderate duration exercise among other factors may be detrimental to basketball performance. To date, no study has examined the effect of fatigue on basketball passing using expert and novice players; hence this research will seek to contribute to the lack of scientific information currently available on the topic. Consequently, the two main aims of this study are (1) to investigate the effects of moderate and high intensity total body fatigue on the performance of the AAHPERD (1984) Basketball Passing Test in expert and novice players and (2) to ascertain if the effects of fatigue on performance are the same regardless of skill level.

METHODS

Participants

Ten physical education students volunteered to participate as the novice basketball players. All students were physically fit and participated in different team sports at collegiate level. Their mean age, height and weight were: 23.30 ± 1.05 yrs, 1.76 ± 0.03 m, and 80.50 ± 5.64 kg respectively. Ten expert basketball players also participated in the study and consisted of a mixture of national division one and two players. Their mean age, height and weight were: 22.50 ± 0.41 yrs, 1.83 ± 0.20 m, and 87.80 ± 4.02 kg respectively. Following institutional ethics approval, informed consent was provided by each participant after being fully informed of the nature and demands of the study.

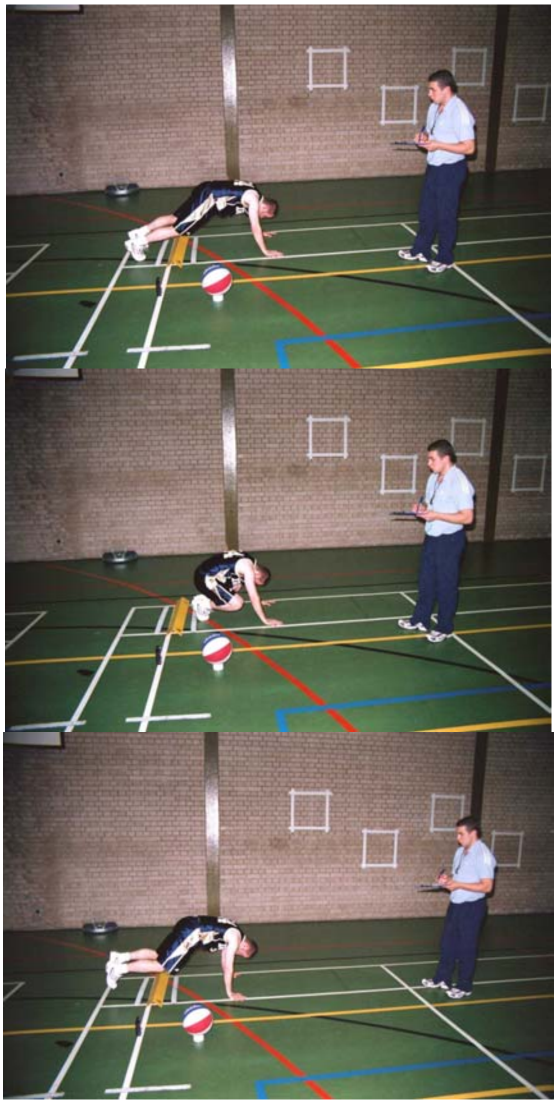

Figure 1. Participant performing squat thrusts (Photographer: Ali Maghoo).

Experimental design

The basketball passing test used in this study was based on a modification of the AAHPERD (1984) Basketball Passing Test. Each participant was given one attempt on the test to familiarise themselves with the protocol. Participants were then given 5-10 minutes warm-up prior to their performance under fatigue conditions. To establish the different fatigue intensities participants were required to exercise to volitional exhaustion and perform as many squat thrusts as possible in one minute (Figure 1). This maximal workload represented the criterion for fatigue and was used to define the moderate and high intensities. These were established by calculating 70% and 90% of the maximum number of squats performed within the minute. This enabled the researchers to establish fatigue intensities based on the fitness level of each individual and ensured each participant was working at the same intensity. The fatiguing task was also chosen because the squat thrusts impacted heavily on the muscle groups used in the passing test such as: gluteals, quadriceps, hamstrings, gastrocnemius and soleus (lower body) and the deltoids, latissimus dorsi, trapezius and abdominals (upper body).

Following this, the participants performed the basketball passing test under three conditions: rest, 70% and 90% of maximal repetitions within a minute. To ensure that each subject was being fatigued to the correct intensity a metronome (Wittner, Germany) was set to the appropriate cadence required. All testing on the three conditions was counterbalanced. To minimise the effects of the previous testing, at least twenty-four hour intervals were given between successive testing sessions. To account for any time-of-day effects all tests were performed within a time difference of ± 2 hours of the first test.

To ensure that performance on the passing test was conducted in a truly fatigued state the following guidelines were set: (1) a very short time lag (3-4 seconds) was allowed from achieving the desired fatigue level and performing the task (2) only one thirty-second test was performed. In the original AAHPERD (1984) Basketball Passing Test participants performed two thirty-second tests and both scores were totalled. The modification in this study was piloted with expert and novice basketball players. These modifications were crucial to the experimental design as the recovery process after fatigue is often considered as a limitation in fatigue experiments (Johnston et al., 1998). In this study the design and modifications allowed the researchers to truly examine on-court the immediate effects of fatigue on basketball passing performance.

The AAHPERD Basketball Passing Test

This test was chosen because it is an appropriate test for assessing basketball passing skills. The test was validated by the American Alliance for Health, Physical Education, Recreation and Dance in 1984, using senior high school students. The test retest approach computed reliability coefficients of .84 to .97 so the test is both valid and reliable. The test also required the participants to pass the ball quickly and

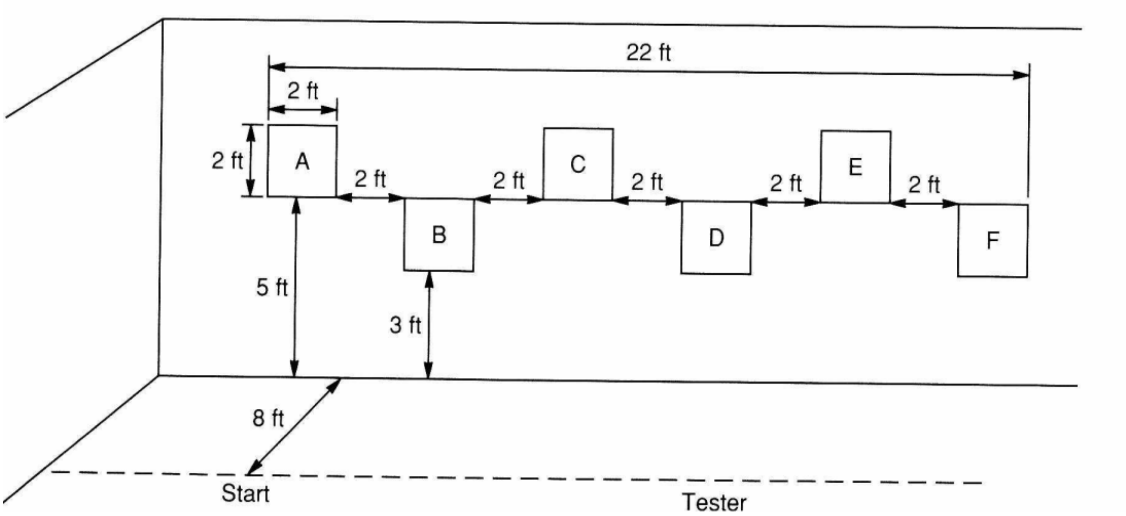

Figure 2. Diagrammatic representation of AAHPERD Basketball Passing Test.

accurately, two elements fundamental to passing in basketball (Krause et al., 1999). Figures 2 and 3 show the diagrammatic representation and set up of the test, which required a smooth wall surface of 30 feet.

Each station for the passing test was prepared as shown (Figure 3). A restraining line 26 feet long was marked out on the floor 8 feet from and parallel to the testing wall. On the testing wall six boxes measuring 2 feet by 2 feet were marked out all 2 feet apart. Moving from the left side of the testing wall, targets A, C and E have their base 5 feet from the floor while B, D and F have their base 3 feet from the floor. This is shown in Figures 2 and 3.

The player stood behind the 8-foot restraining line, holding a basketball and facing the far left wall target (A). The experimenter then played the CD, which emitted a three-bleep countdown, and the fourth bleep signalled the start of the test. Following the fourth bleep, each player performed a chest pass to the first target square (A), recovered the ball while moving to the second target square (B) performed a chest pass to the second target (B). The player then continued this action until they reached the last target (F). While at the last target (F), they threw two chest passes then repeated the sequence by moving to the left passing at targets E, D, C and so on. The only modification to the test was that it continued for just thirty seconds. Only chest passes were allowed.

The scoring of the test was as follows:

- Two points were awarded for each chest pass that hit the target or on the target lines.
- One point was awarded for every pass that hit between the targets.
- No points were awarded if a player's foot was on or over the restraining line, or if a pass other than a chest pass was used.

Figure 3. Set-up of the AAHPERD Basketball Passing Test (Photographer: Ali Maghoo).

Figure 4. Participant Performing the AAHPERD (1984) Basketball Passing Test (Photographer: Ali Maghoo).

The test score was obtained by totalling all the points scored over the duration of the thirty-second test.

Statistical analysis

The results were expressed as the mean ± SEM. Descriptive analysis was performed using standard methods (Table 1). A 3 X 2 way ANOVA with repeated measures was carried out on performance scores. The within subject factors were performance at rest, performance following moderate fatigue and performance following high intensity fatigue. The between subject factor was level of skill. Between-group differences were then examined using two separate independent t-tests. One independent t-test examined the difference between the changes in scores from the rest condition (Δ) to 70% between the experts and novices. The second independent t-test examined the difference between the changes in scores from the rest condition (Δ) to 90% between the experts and novices. To examine within-group differences, 2 separate ANOVA's with repeated measures were carried out on the performance scores of the expert and novice players' data. Bonferroni adjustment post hoc was used in the case of significant F scores. SPSS Version 13.0 (SPSS Inc., Chicago, IL) was used for all statistical calculations. The level of significance was set at 0.05.

RESULTS

The 3 X 2 way ANOVA revealed a highly significant (F 2,36 = 5.252, p = 0.01, power = 0.801) level of fatigue by level of skill interaction. From the interaction graph (Figure 5) it is clear that in both groups there is a decline in performance as fatigue intensity increases. There is also evidence to suggest that the performance of the players across the 3 fatigue intensities varies depending on whether they are experts or novices. From Table 1 it is clear

Table 1. Descriptive statistics.

Variables	N	Minimum	Maximum	Mean	SEM
Score (Rest) Expert Players	10	40.00	58.00	48.90	2.11
Score (70%)Expert Players	10	38.00	56.00	48.30	1.86
Score (90%) Expert Players	10	34.00	54.00	43.60	2.12
Change from rest (Δ) to 70% Expert Players	10	-4.00	6.00	.60	1.00
Change from rest (Δ) to 90% Expert Players	10	1.00	14.00	5.30	1.24
Score (Rest) Novice Players	10	40.00	59.00	50.60	1.75
Score (70%) Novice Players	10	36.00	58.00	46.20	1.87
Score (90%) Novice Players	10	31.00	48.00	39.70	1.38
Change from rest (Δ) to 70% Novice Players	10	1.00	10.00	4.40	.87
Change from rest (Δ) to 90% Novice Players	10	4.00	17.00	10.90	1.22

Abbreviations: SEM = Standard Error of the Mean, Δ = Delta.

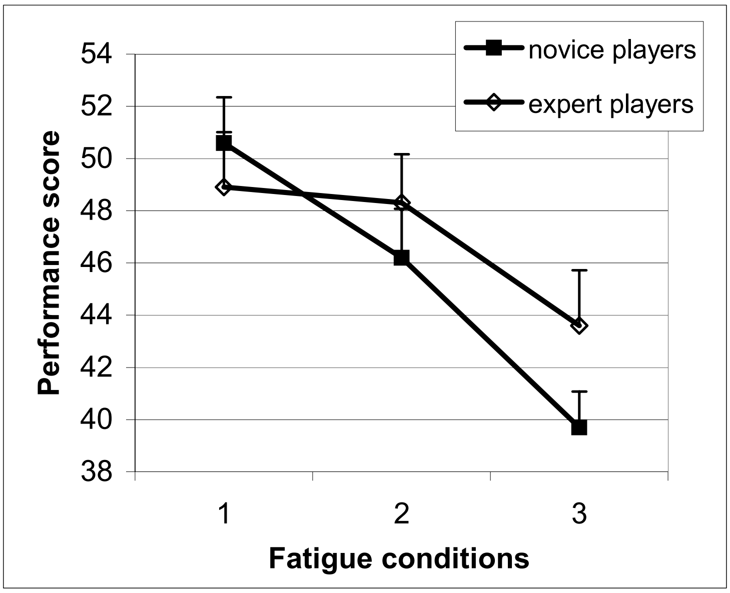

Figure 5. Basketball-passing scores for expert and novice basketball players following rest (1), moderate (2) and high intensity fatigue (3).

that the decline in performance of the novice players declines from 50.6 at rest to 39.7 following high intensity fatigue. The decline in the performance of the experts however, is not as steep and drops from 48.9 at rest to 43.6 following high intensity fatigue. There seems to be a much greater decline in the novice players' performance therefore, when compared to the expert players.

The first independent t-test which examined the rate of decline or the changes in scores from the rest condition (Δ) to 70% between the experts and novices showed that there is a highly significant difference in the decline in performance between the two groups ($t_{(18)} = 2.861$, $p = 0.01$). Table 1 again reinforces this with the mean decline in experts at 0.60 ± 1.00 and 4.40 ± 0.87 for the novices. In the experts, clearly there is little difference between performance at rest and that following moderate fatigue. In the novices however, there is a clear deterioration in performance (Figure 5).

The second independent t-test examined the rate of decline from the rest condition (Δ) to 90% between the expert and novice players. This again showed a highly significant difference in the decline in performance between the two groups ($t_{(18)} = 3.215$, $p = 0.005$). Examination of the descriptive data (Table 1) again shows that the mean score for the experts decline was 5.30 ± 1.24 and for the novices was 10.90 ± 1.22. Here again while there is a significant difference in the decline from rest to 90% fatigue in both groups, the rate of decline is much greater in the novice players (Table 1). The results of the two independent t-tests substantiate the claim that the decline in performance in the novice players is much greater than that in the expert players. The effects of fatigue on basketball passing therefore are different depending on level of skill.

To examine within-group differences, two further ANOVA's with repeated measures were conducted on the novice players and the expert players data separately. The first ANOVA with repeated measures revealed a highly significant ($F_{2,18} = 40.01$, $p = 0.000$, power = 1.000) difference between the performance scores of the novice basketball players at rest, 70% and 90%. Using the Bonferroni adjustment, results indicated a highly significant difference ($p = 0.002$) between scores at rest and 70%, a highly significant ($p = 0.000$) difference between performance scores at rest and 90%, and finally, a highly significant difference ($p = 0.006$) between performance at 70% and 90%. Examination of the descriptive data (Table 1) indicates that the mean scores of the novice players following rest, 70% and 90% total body fatigue were 50.60 ± 1.75, 46.20 ± 1.87 and 39.70 ± 1.38 respectively. This indicates a steady decline in performance as fatigue intensity increased.

The second ANOVA with repeated measures also revealed a highly significant ($F_{2,18} = 10.47$, $p = 0.001$, power = 0.971) difference between the performance scores of the expert basketball players at rest, 70% and 90%. Using the Bonferroni adjustment, results indicated a highly significant ($p = 0.006$) difference between scores at rest and 90% and a significant difference ($p = 0.038$) between scores at 70% and 90%. Fundamentally however, there was no significant difference between performance at rest and performance at 70%. Examination of the descriptive data (Table 1) indicates that the mean scores for the expert players following rest, 70% and 90% total body fatigue were 48.90 ± 2.11, 48.30 ± 1.86 and 43.60 ± 2.12 respectively. Unlike the novices, with the expert players there was no difference between performance at rest and performance following fatigue at 70%. Fatigue at 70% therefore, does not impair the performance of the expert players in this study. As with the novice players however, there was still a clear detriment in performance following high intensity fatigue (Figure 5).

DISCUSSION

Due to the fact that many sports skills are performed in a fatigued state, there is a need to assess skilled performance in this condition. To date, much research examining the effect of fatigue on performance has been conducted in laboratory settings, vastly different from those encountered in the sporting field. The design of the current study was such that the investigators could carry out all experimental work in an appropriate field setting. While the conditions used in this investigation were appropriate for examining the effects of moderate and high intensity fatigue on basketball passing skills, the authors acknowledge that the fatiguing task is not without limitations in terms of ecological validity. We also acknowledge that the fatiguing task performed does not fatigue the muscle groups in the upper body to the same degree as the lower body. The justification for this type of fatiguing task however, is clearly outlined in the earlier sections of this paper. Furthermore, an appropriate basketball-specific fatigue protocol that truly replicates match play exercise patterns would have been utilised for this study but currently none exists. Future empirical work needs to carefully consider this so that the fatigue experienced is very similar to that experienced in match play.

With respect to our results, the first notable finding was that the mean scores at rest were slightly higher in the novice players than the expert basketball players, possibly due to motivational factors. Additionally, the novice players were physically very fit, and demonstrated a very high intensity of effort during all testing. Fundamentally however, this study has demonstrated that there is a highly significant ($p = 0.01$) level of fatigue by level of skill interaction (Figure 5). The within and between-group statistical test results also show this to be true where the rate of decline in the basketball passing performance of the novice players is much greater than that in the expert players. The results support previous work where fatigue was also accompanied by a decline in skill (Al-Nakeeb et al., 2003; Berger and Smith-Hale, 1991; Davey et al., 2002; Lyons et al., 2006; Mohr, 2003). This research highlights however, that experts exhibited no statistical difference in performance following moderate fatigue. Finally, the expert players were better able to cope with high intensity fatigue conditions and maintain a higher level of performance compared to novice players.

Comparison of our findings to previous investigations is difficult because of large variations in experimental designs from study to study. Add to this the distinct lack of research on fatigue in basketball, leaves researchers with a limited basis for comparing findings. Our findings do concur however, with those of Ivoilov et al. (1981) where basketball-shooting performance deteriorated following high intensity fatigue. This finding was consistent in both expert and novice players in the current research.

Conversely, our findings are contrary to those of McMorris et al. (1994) where passing performance was significantly better following moderate fatigue than at rest. In our study however, there was a decline in passing performance following moderate intensity fatigue compared to rest in both groups but the decline was only statistically significant ($p = 0.002$) in the novice group. Mean performance scores in fact, were almost identical in the expert players at these two intensities (Table 1) suggesting that experts are able to compensate their performance at this intensity to ensure optimal performance. This compensation could take the form of recruitment of additional motor units and rotating between different synergist muscles to compensate for reduced muscular efficiency (Green, 1990). It seems therefore, that in expert players fatigue needs to be at a very high intensity for a significant deterioration in performance to be exhibited. Finally, McMorris et al. (1994) also found no difference between performance following moderate and high intensity fatigue. Again this is contrary to the current study where there was a significant ($p = 0.038$) difference in the performance of the expert players and a highly significant ($p = 0.006$) difference in the performance of the novice players. Fundamentally, while the passing test used by McMorris and colleagues is similar to this research, the fatiguing tasks are very different. Comparisons drawn therefore, must be interpreted with this is mind.

As detailed previously, a number of theories have been developed attempting to explain the relationship between exercise, arousal and performance. Despite some limitations, the weight of the scientific evidence still continues to favour the Inverted-U theory (Landers and Arent, 2001). The results of this research however, do not conform to an inverted-U effect. Similarly, the results do not conform to Easterbrooks' (1959) Cue Utilisation Theory, which would predict optimal performance at moderate levels of arousal. On the contrary, our results suggest that passing performance deteriorates in both experts and novices following moderate intensity fatigue. Again at high intensity fatigue the inverted-U theory and cue utilisation theory would predict that performance should return to baseline level when in the current study performance deteriorated significantly compared to rest in both groups.

In terms of explaining the expert-novice differences however, Drive Theory, developed by Hull (1943) potentially provides an explanation for the novice players' results. Within the novice group there was a progressive decline in basketball passing performance as arousal or fatigue intensity increased. This agrees with Drive Theory, which would also predict such an effect because in the novices' habit patterns are not strongly formed. Drive Theory also predicts optimal performance at low arousal levels in the novices', which mirrors our findings. At high levels of fatigue however, performance will deteriorate due to the fact that habit strength is low and so incorrect responses are likely to dominate in the novices. Again our findings show this to be the case. However, the basketball passing performance of the experts in this study is contrary to what Hull (1943) and Oxendine (1984) would hypothesise. In experts, because habit patterns are strongly formed, basketball passing should be optimal at a high level of arousal (following high intensity fatigue) especially for simple skills such as that employed in this study. However, in our research, there was in fact, a highly significant ($p = 0.006$) deterioration in basketball passing compared to rest.

The results of this study may be better explained however, in terms of the Multi-Dimensional Allocation of Resources Theory (Kahneman, 1973) that predicts a deterioration in performance following high intensity exercise, as cognitive effort cannot focus attention solely on task-relevant information. Within both the novice and expert groups this was clearly the case. From Table 1 it is clear that in the expert group, performance declined by 5.30 ± 1.24 while in the novice group performance declined by 10.90 ± 1.22. Consequently, while the distractibility referred to by Kahneman (1973) is evident in both groups, it is higher in the novices. Both groups therefore, are unable to ignore perceptions of pain, distress and fatigue and focus on the passing test. This divided attention ultimately leads to a deterioration in passing performance, which is clearly evident in both groups. Experts however, despite a significant decline in passing performance following high intensity fatigue seem better able to focus on task relevant information, thereby maintaining a higher standard of performance than the novice players.

More specifically, the performance of both groups at rest can also be explained based on this theory. According to Kahneman (1973) performance at rest can be optimal if cognitive effort can allocate sufficient resources to the task. In the present investigation this was found to be true for both groups. There is also a possibility that the novice players allocated additional resources at rest, thereby achieving a slightly higher rest score than that of the expert players. Further research is warranted therefore, to preclude any definitive statements regarding the theoretical effects of fatigue on performance.

Trying to identify the physiological mechanisms underlying fatigue effects on performance in this research is both challenging and highly complex. Additionally, mechanisms of fatigue are still not understood and most likely involve multiple sites (Lee et al., 2000). These mechanisms, underlying causes and sites have been argued and counter argued elsewhere in the scientific literature. McKenna (2003) points out however, that in most cases fatigue predominantly occurs in the periphery and given the nature of the fatigue task in this study, it is likely that causes lie in the periphery. The details of peripheral impairments due to fatigue can be found in reviews published elsewhere (Coggan and Coyle, 1991; Enoka and Stuart, 1992; Fitts and Metzger, 1993). The likelihood that the deterioration in motor performance can be traced to a single common event or process however, now appears naïve (Green, 1990).

Despite this, the following points need consideration in terms of the present research findings. Firstly, the fatiguing task in this study was very much an anaerobic-type task and very demanding of energy as was the passing test. The fatiguing task impacted heavily on a number of major muscle groups in the lower body such as the quadriceps and gastrocnemius. It is likely therefore, that muscle glycogen degradation in large muscle groups such as the quadriceps, which were then subsequently used in the passing task, was one causative factor. In the debriefing sessions participants often remarked following the high-intensity fatigue session that by the end of the passing-test they had nothing left in their legs. Given the fatiguing task and the ensuing passing task it is most likely that the participant would have experienced a disproportionate decrease in muscle glycogen, leading to reduced ATP resynthesis. Combined, these would certainly have limited performance on the basketball passing task following high intensity fatigue in both groups of players.

Given the anaerobic nature of the fatiguing task it is likely that metabolic by-products such as lactic acid contributed to the deterioration seen in the performance in both groups at a high intensity. Exercise induced accumulation of lactic acid in skeletal muscle and the resulting decrease in cellular pH have been widely considered to contribute to fatigue (Westerblad et al., 1991; Fitts, 1994). Again while not directly measured in our study, lactic acid in the legs was frequently cited by the participants in the debriefing sessions. There are clearly many other metabolic factors that have potential to disrupt energy provision and muscular contraction but discussion of these is beyond the remit of this work.

From observation of the testing and post-test briefing sessions the following points also need consideration. It is very clear in some participants that the distractibility cited by Kahneman (1973) was a factor in limiting performance. In both groups it was also evident following high intensity fatigue, that players were experiencing a degree of discomfort and subsequent disruption in motor control. The novice players particularly had difficulty maintaining balance and postural stability immediately following both fatigue conditions, a finding not uncommon in the scientific literature (Vuillerme et al., 2002; Johnston et al., 1998). Consequently, decreased postural stability on the part of the players should not be overlooked as a factor influencing performance while fatigued.

Secondly, information provided by the novice players in the debriefing sessions frequently revealed a feeling of ‘weakness’ in their legs and a distinct lack of power, following fatigue at a high intensity. The lack of power could be due to a number of physiological reasons but also due to the fact that when muscles undergo repeated shortening contractions a greater force loss is evident than with repeated isometric contractions (James et al. 1995, cited in Cairns 2005). The fatigue task in this research certainly required repeated shortening contractions and so this may account for the distinct lack of power. In the case of this research, the lack of power manifested itself through weak or inaccurate passes, subjects losing control of the ball and on some occasions players stepping over the restraining line all of which decreased the score obtained. Weaker passes were those where the ball was not passed with sufficient power or force against the wall for the rebounding ball to be caught by the participant before bouncing. Therefore, the decline in performance on the basketball passing test could be due directly or indirectly to the inability of the specific muscle groups to cope with the demands of the task in terms of speed, accuracy or both. This point is crucial in that the test relied on a combination of speed and accuracy (as is often the case in sports) and ultimately performance deteriorated. There are possible implications here for coaching and training in basketball.

Linked to this somewhat was the observation that following high intensity total body fatigue there was a detrimental impact on the players reaction to the ball rebounding off the wall which manifested in the form of players fumbling the ball. This is similar to the findings of Legros et al. (1992). This was particularly evident again in the novice players following high intensity fatigue. In the novices, it is clear that under conditions of intense exercise, essential elements in performance such as handball coordination and movement cannot be integrated properly and so performance level deteriorates. This may be a determining factor that separates expert and novice players during performance.

The third point which is crucial to note is that the design of this study may provide some evidence as to why a decline in performance was evident following both fatigue intensities in both groups. Fatigue is considered to be a continuous rather than a failure-point phenomenon (Cairns, 2005). Speed of recovery can be an issue if measurements are not made immediately on exercise cessation. McMorris and Graydon (2000) highlighted this in a previous study, where reaction time was hypothesised to decrease following maximal exercise (due to reduced acetylcholine, potassium, ATP, and phosphocreatine in muscle). However, as the mean task time was 2.33min, a significant amount of replenishment most likely had occurred. Astrand and Rodahl (1977) also add that replenishment of these chemicals following exercise is especially fast in trained athletes. Plasma concentrations of epinephrine for example, are known to dissipate quickly when exercise is stopped (Kjaer, 1989) with as much as a 35% reduction within 1 minute and a 50% reduction within 2–3 minutes. It is also acknowledged that recovery in muscular strength is fast in trained athletes following exercise. However, it is extremely unlikely that such recovery was a factor in this study because passing performance was conducted immediately following (3-4 seconds) fatigue and the total duration of the passing test was 30 seconds. Consequently, this research has allowed the researcher to investigate the immediate effect of fatigue on performance. Replenishment of chemicals or recovery in muscular strength/power is therefore unlikely given our design.

CONCLUSION

To conclude, in basketball there is currently very little literature examining the effect of fatigue of any type on skilled performance. The results of this study however, have demonstrated clearly a potential decrement in basketball passing following a short bout of high intensity exercise regardless of skill level. The results do suggest however, that the deterioration from rest to high intensity fatigue is very different in expert and novice players. More specifically, in experts fatigue has to be at a very high level for a detriment in performance to be exhibited whereas in the novices there is a consistent detriment in performance as fatigue intensity increases. The results of this work may have implications for basketball trainers and strength and conditioning coaches at all levels of the game. More specifically, there may be a need for these professionals to integrate short bouts of high intensity anaerobic-type exercise into skills training. According to Hoffman and Maeresh (2000), anaerobic-type training in Basketball should be initiated in the pre-season training program. It is fundamentally important also that this training should simulate as much as possible the high-intensity exercise bouts typically experienced during the game. This training, if integrated into drills and skills work may enable players to maintain a higher standard of play and better cope with the demands of the game on court.

This study has raised many fundamental questions regarding the effect of fatigue on performance and further research is imperative. Future work needs to use tests that demonstrate high reliability and ecological validity. Future work could be directed towards the effect of sport-specific fatigue on aspects of performance such as concentration, compensatory mechanisms, biomechanical aspects of performance, anticipation and examining whether differences in level of performance are linked to one or more of these factors. The implication of such research would be of immense value to coaches, trainers and exercise physiologists alike.

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KEY POINTS

- Aim: to investigate the effect of moderate and high intensity total body fatigue on basketball-passing accuracy in expert and novice basketball players.
- Fatigue intensity was set as a percentage of the maximal number of squat thrusts performed by the participant in one minute.
- ANOVA with repeated measures revealed a significant level of fatigue by level of skill interaction.
- Despite a significant detriment in passing-performance in both novice and expert players following high intensity total body fatigue, this detriment was not as steep in the expert players when compared to the novice players.

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