



Validity and Reliability of Specific Basketball Motor Skill Simulation Protocol for Inducing Fatigue Based on Some Physiological Indicators

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Abstract

The aim of the study was to verify the validity and reliability of a basketball-simulated physical exertion test designed to induce fatigue, by measuring heart rate (HR), lactate concentration (LA) and the Rating of Perceived Exertion (RPE). The study sample consisted of 20 basketball players from leading teams in the Iraqi Premier League, with an average age of (21.50 ± 3.67) years, With a body mass of (80.50 ± 11.71) kg and a height of (189.00 ± 7.75) cm, the basketball-simulated physical exertion test protocol to induce fatigue consisted of four exercises performed consecutively following a warm-up. Heart rate was measured remotely before, during and after the exercise using a Polar Verity Sense remote heart rate monitor, whilst lactate levels were measured before the exercise and five minutes afterwards using a Lactate Pro2 device. from Arcray; the perceived exertion (RPE) was also assessed upon completion of the test using the modified Borg scale (CR-10). SPSS V22 was used to analyse the research results. The results demonstrated the validity and reliability of the protocol, as all experts agreed that the protocol was suitable for basketball players and that it was able to distinguish between high and low levels of performance. The results also demonstrated the reliability of the test, with the correlation coefficients between groups for all fatigue indicators being higher than 0.70, Furthermore, the Bland-Altman plot also demonstrated the reliability of the protocol, as the differences between the first and second tests were distributed around the mean difference and fell within the upper and lower limits of the 95 per cent confidence interval for the three fatigue indicators.

Keywords: neuromuscular fatigue, exercise simulation protocol, fatigue induction, fatigue in basketball.

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Introduction

Basketball is considered one of the most enjoyable team sports due to its speed, excitement and the aesthetic appeal of the skills performed, as well as its reliance on tactical manoeuvres characterised by changes of direction and position and the use of various skills (dribbling, passing, shooting, and others). What sets this team sport apart is the player's freedom of movement and the fact that players from the opposing team cannot make direct physical contact with them which allows players to showcase their individual skills and move freely within the specified time limits. A regulation basketball court measures 15×28 metres, on which five players from each team compete to score as many points as possible over the course of the match, which consists of four quarters, each lasting 10 minutes of actual playing time. Furthermore the rules of the game prohibit passive play by setting limits on the duration of an attack the time the ball may be in the opposing team's half the time a player may hold the ball, the time spent in the restricted area, and the time taken to bring the ball into play from the sidelines. It therefore requires a high level of both aerobic and anaerobic fitness to enable players to complete the four quarters of the match.

Basketball is characterised by high-intensity performance interspersed with periods of lower exertion or rest, and its movements and skills are characterised by rapid running and repeated jumping (Abian-Vicen et al., 2014) (Qarouach et al., 2024) (Stojanović et al., 2018). This requires repeated physical exertion at high speed and intensity, involving explosive movements which in turn necessitates complex physiological and biomechanical requirements (Andreyo et al., 2023). In high-intensity basketball matches players perform high-intensity movements for 15 per cent of the match duration, at a heart rate of 169 ± 9 bpm, which is approximately 90 per cent of the maximum heart rate (García et al., 2020) (Vázquez-Guerrero et al., 2019). As mentioned above, basketball relies heavily and primarily on the anaerobic energy system for the performance of movements the technical skills required and the demands of the game this does not mean that aerobic training is of no use or should be neglected. Indeed, the anaerobic system accounts for 90 per cent of the energy required in basketball compared with 10 per cent for the aerobic system (Powers & Howley, 2018). From a bioenergetic perspective, exercise and physical fitness can be categorised according to the predominant metabolic pathways for the production of adenosine triphosphate (ATP). Both the anaerobic phosphagen system and the anaerobic glycolytic system produce ATP at high rates, but in relatively small and limited quantities whilst aerobic metabolism (or the aerobic energy system) produces ATP at a slow rate but in large quantities. The phosphagen energy system predominates in strength and power movements that require anaerobic capacity and maximum instantaneous effort lasting for a few seconds (less than 15 seconds). Meanwhile, the phosphagen and anaerobic glycogenolysis energy systems together contribute significantly to activities requiring a combination of anaerobic power and endurance, which last for approximately 15–30 seconds, and the closer the duration of the exercise gets to 30 seconds the greater the contribution of the anaerobic glycogenolysis system. Basketball is one of the fastest team



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sports and is characterised by exceptional movements such as sprinting, changes of direction, quick shots, rebounds and blocked shots (Gottlieb et al., 2014). This means that basketball players need a high level of ability to demonstrate the speed, strength and capacity required to perform successfully in a match (Delextrat and Cohen, 2008). Many of the key movements performed by basketball players during a match rely on horizontal movements (sprinting and changes of direction) vertical movements (jump shots and rebounds) and combinations of movements within each of these planes; these high-intensity movements are typically performed intermittently throughout the match (Gottlieb et al., 2014).

Scientific studies indicate that basketball requires explosive strength in both the upper and lower limbs, as well as the rate of force development (RFD) – which provides an indication of the speed at which muscular force is generated and transmitted – agility, coordination and speed (Read et al., 2014). Furthermore, basketball requires a high level of technical skills such as shooting, dribbling, passing, rebounding and defensive movements, amongst others; these are essential skills for successful performance and require continuous training to master. Research indicates that technical, tactical, psychological and physiological abilities are all crucial to performance in basketball (Luo et al., 2023).

The above requires measurement during a basketball player's actual performance in order to assess their physical and functional efficiency whilst playing, as well as to measure the neuromuscular fatigue resulting from physical exertion. However, teams or tournament regulations often do not permit the monitoring and measurement of players during or immediately after performance. Researchers therefore design tests or movement protocols that simulate basketball in terms of performance and timing. These protocols are an effective way of assessing players both during matches and outside competitive tournaments (Williams et al., 2010) (Waldron et al., 2013) In this context, previous studies have highlighted the importance of various types of measurements in assessing basketball players; for instance, a study by Fox et al. (2017) examined movement analysis, timing, and cardiovascular and respiratory parameters. Meanwhile, the study by Boddington et al. (2019) investigated the validity and reliability of a modified jump-shooting accuracy test. Meanwhile the study by Kostopoulos et al. (2004) utilised a protocol consisting of a 10-minute high-intensity exercise session simulating a basketball game to assess exercise-induced muscle damage. Basketball-specific simulation protocols are the most common and widely used in scientific research; they consist of 12 minutes of physical exertion simulating a basketball match (Scanlan et al., 2012). Ferioli et al. (2024), on the other hand, proposed a protocol simulating a basketball match, lasting a total of 63 minutes and comprising periods of exercise at varying intensities and rest periods. It is clear from the above that, whilst the protocols described are reliable and valid, they may not be suitable for inducing fatigue in order to record certain variables, such as the occurrence of transient neuromuscular fatigue using an electromyograph (EMG) or other motion-synchronized

devices as it is impractical to keep the device attached and carry out the protocol for a very long period exceeding 3 minutes.

Method and Tools

The study sample consisted of 20 basketball players from teams in the Iraqi Elite League who were selected using a purposive sampling method. Their mean age was (21.50 ± 3.67) years, mean body mass was (80.50 ± 11.71) kg, and mean height was (189.00 ± 7.75) cm. A basketball-simulated physical exertion test protocol was administered to induce fatigue. The test consisted of four exercises performed sequentially following a warm-up that included light jogging, stretching, direction changes, and long-range shooting for a duration of (8–10 minutes) as follows:

- Exercise 1 (Defensive Moves): Start by running from the baseline in the center toward the far three-point line, stop, take defensive steps to the right along the far three-point line, and return to the starting point. Then repeat the same movement but from the left side. Repeat the exercise twice without a break (2 repetitions).

Exercise 2 (Side-to-Side Movements Toward the Board): Perform the movement from the right side twice in a row, followed by two steps to the left; then perform the movement from the left side twice in a row. Repeat 3 times on each side without a rest.

Exercise 3 (High dribble with change of direction): The half-court is divided into three lines. The first line is under the basket (the baseline) starting on the right-hand side and 2 metres from the touchline. The second line divides the half-court in half, 7 metres from the baseline (with the first marker placed 2 meters beyond it). Then, bounce the ball whilst changing direction between the three markers continuing to bounce it until you reach the centre line then bounce it back quickly and high to the starting point (the basket). Exercise 4 (Back-and-forth running): Half the court is divided into three lines: a first line under the basket in the center to start from (the baseline) a second line dividing the half-court into two equal halves at a distance of 7 meters and a third line at the centre of the court at a distance of 14 meters (the center line). The drill is performed by starting with a run from the baseline towards the second line 7 metres away and returning to the baseline, and then running from the baseline towards the third line 14 metres away and returning to the baseline, and then repeat the same movement a second time. Run from the centre line to a point 14 metres away and back to the baseline (under the basket) the exercise is repeated twice without stopping.

To ensure that the basketball-simulated exercise test protocol brings players to the point of fatigue remote heart rate measurements were taken before during and after the exercise using a Polar Verity Sense remote heart rate monitor. as the player must reach a heart rate of at least 80 per cent of their maximum heart rate (HRmax) whilst performing the game-simulation test. Lactic acid levels were also measured before the exercise and five minutes afterwards using the Lactate Pro2 device from Arcray, whilst the perceived exertion (Rating of Perceived Exertion – RPE) after completion of the test. The modified 10-point Borg scale (CR-10) was used to determine the intensity of the basketball-simulated exercise. The

main experiment for this research was conducted in the indoor basketball hall at the Faculty of Physical Education and Sports Sciences, University of Baghdad, at 9.00 am. The statistical package SPSS V22 was used to analyse the research results.

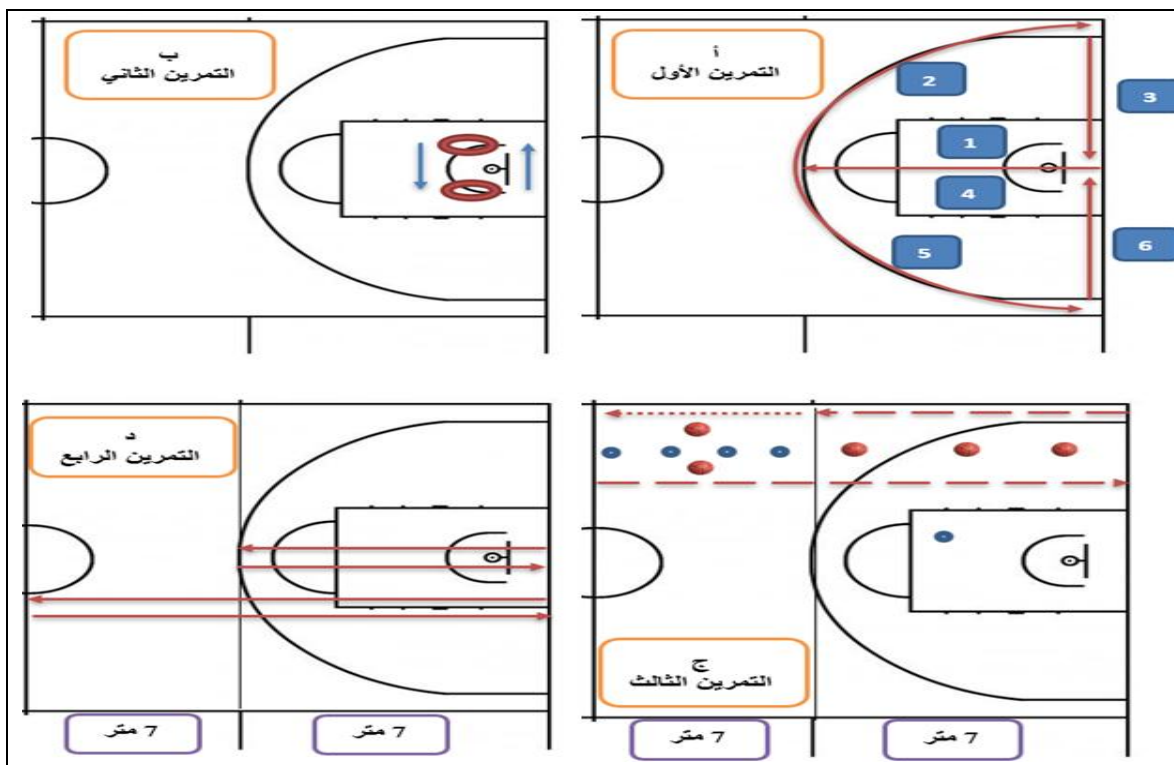


Figure1. shows a diagram of the protocol for the basketball-simulated physical fitness test

Results

Table1. shows the experts' agreement on the basketball-simulated physical exertion test designed to induce fatigue

Test	Number of experts	Suitable	Not suitable	Agreement Rate
A Basketball-Simulated Physical Stress Test to Induce Fatigue	5	5	0	%100

Table2. shows the results of the differences between the lower and upper groups in terms of heart rate measurements, perceived exertion and lactate concentration

SIG	T	Upper Group		Lower Group		Variable
		SD	mean	SD	mean	
0.001	5.583	3.507	183.600	3.286	171.600	Heart rate (bpm)
0.000	7.155	0.224	8.400	0.447	6.800	Effort rating (points)
0.001	7.186	2.248	18.160	0.980	10.280	Lactic acid (mmol)

n = 20. significant at the 0.05 significance level. DF (8).

Table 3. shows the stability coefficients for the test method and its repeatability in measuring heart rate, assessing exertion and determining lactate concentration

correlation coefficient (ICC)				Variable
Measurement	Single	Kornbach	correlation	
Mean	measurement			
0.814	0.686	0.815	0.765	Heart rate (bpm)
0.820	0.694	0.822	0.728	Effort rating (points)
0.711	0.552	0.787	0.765	Lactic acid (mmol)

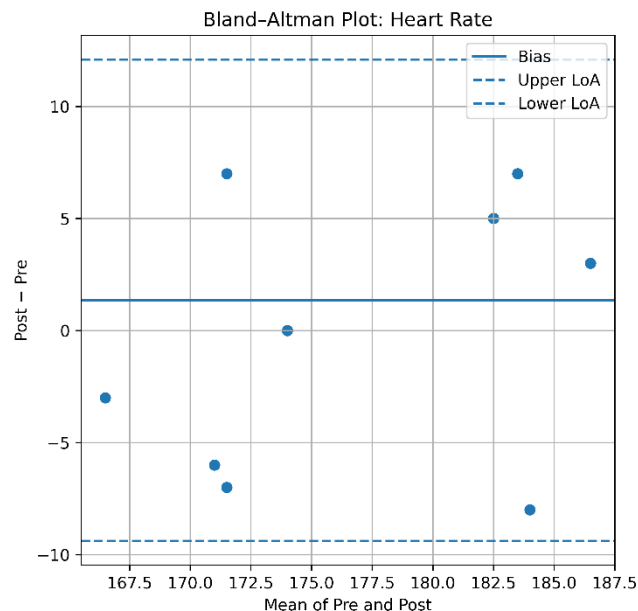


Figure2. shows a Bland-Altman plot for the heart rate variable

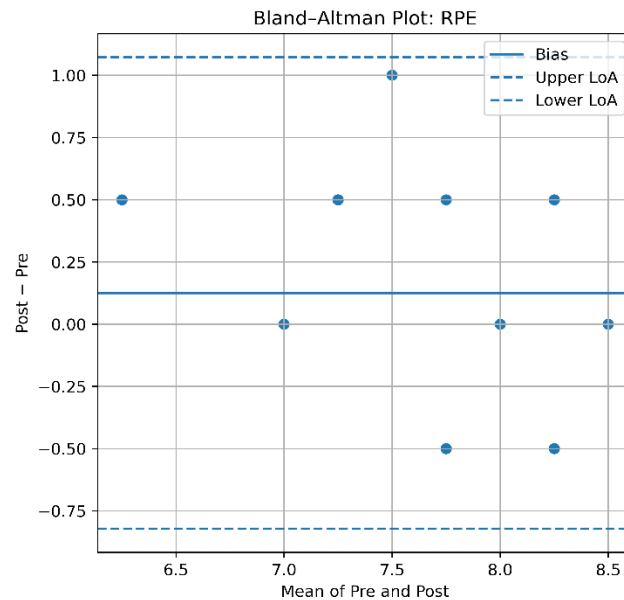


Figure3. shows a Bland-Altman plot for the RPE (Rated Perceived Exertion) variable

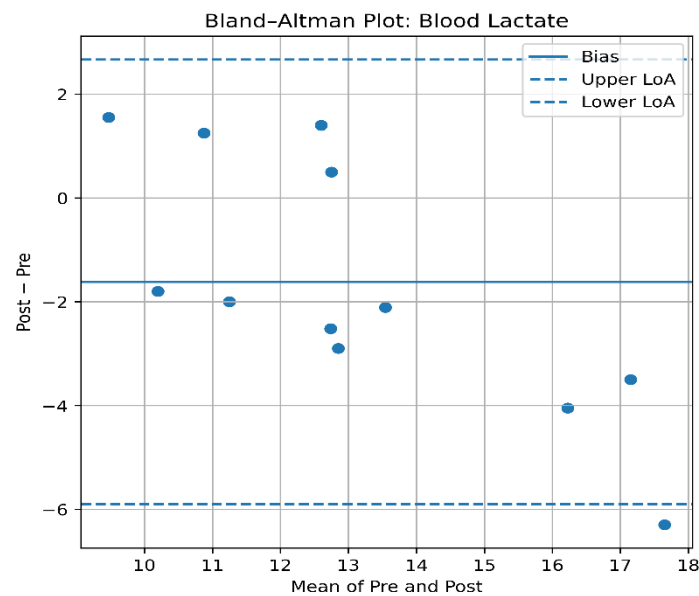


Figure 4. shows a Bland-Altman plot for the blood lactate variable



Discussion

Table (1) shows that the test has face or logical validity, as it clearly measures the required skill or ability (Miller, 2006). This is the basis on which the basketball-simulated physical exertion test was designed to induce fatigue, as it involves genuine physical and skill-based exertion at a high intensity which is logical for inducing genuine fatigue in the players. The exercise performed led to a significant rise in blood lactate levels and the heart rate reaching sub-maximal levels, at no less than 85 per cent of the maximum heart rate for each player. As shown in Table 2 the validity of the cross-sectional comparison between the minimum and maximum values of the indicators of fatigue—namely, heart rate, lactate concentration and the assessment of exertion—which reflect the intensity of physical exertion used in the basketball-simulated exercise test to induce fatigue. In addition, the significant differences between the minimum and maximum values demonstrate the reliability of the test in distinguishing between low and high measurements and scores.

Table (3) illustrates the reliability of the test using the test method and its repetition for the purpose of verifying the physical exertion test simulating a basketball game to induce fatigue, and presents the simple correlation coefficient and the inter-group correlation coefficient (Intraclass Correlation – ICC) for the indicators of fatigue, namely heart rate, lactate concentration and perceived exertion.

It appears that the inter-class correlation coefficients for all three variables were greater than 0.70, which supports the reliability of the test; furthermore, the simple correlation coefficients and the Cronbach's alpha values were also greater than 0.70, which further reinforces the reliability of the test (Alkazaly & Altay, 2023).

As shown in the Bland-Altman plot (Figures 1–2–3) verifies the reliability of the basketball-simulated exercise test designed to induce fatigue in measuring heart rate, lactate concentration and the assessment of exertion, showing the distribution of differences between the first and second tests in terms of the mean difference and its confinement within the upper and lower limits of the 95 per cent confidence interval.

The increased demand placed on the circulatory system is to meet metabolic requirements in order to sustain performance; in fast-paced, intermittent sports such as basketball, where players perform rapid, explosive and repetitive movements at high intensity, this leads to stimulation of the sympathetic nervous system, resulting in an increased heart rate to boost cardiac output in order to ensure that oxygen reaches the working muscles whilst increasing the removal of metabolic waste products.

The maximum heart rate (HRmax) of the players following physical exertion simulating a basketball match reached 198.5 bpm which is equivalent to 88 per cent of maximum intensity. Furthermore, during a basketball match lasting 40 minutes players cover a distance of 5–6 km at lactate levels above the lactate threshold and at a heart rate exceeding 85 per cent of their maximum heart rate (Stojanović et al., 2018) (Berkelmans et al., 2018). As demonstrated in a study (Scanlan et al., 2018). Furthermore, basketball



places very high functional demands on the body, with the heart rate reaching (180 ± 5.7 bpm), which is equivalent to (90.8 ± 4.0 per cent) of the maximum heart rate (HRmax).

The maximum heart rate reached by adult basketball players (88% HRmax) falls within the 'Vigorous' category, according to the American College of Sports Medicine (ACSM) classification. The ACSM classifies heart rates as follows: above 95 per cent of maximum is 'near maximum', 77–95 per cent is 'vigorous', 64–76 per cent is 'moderate', 57–63 per cent is 'light', and below 57 per cent is 'very light' (Garber et al., 2011).

This lends validity and credibility to the basketball simulation test, as it was able to physiologically stimulate the body and bring it to a state of neuromuscular fatigue. Indeed, as heart rates rise to their maximum limits as a result of physical exertion, there is a reduction in muscle glycogen, muscle damage or injury, an increase in core body temperature, and insufficient resynthesis of high-energy phosphates (Scanlan et al., 2015).

Furthermore, elevated blood lactate levels were observed following physical exertion simulating a basketball match, indicating a high demand by the body for anaerobic energy to sustain performance. Blood lactate levels rise due to increased reliance on the anaerobic breakdown of glycogen (anaerobic glycolysis) – whether from muscle glycogen or blood glucose – in order to rapidly produce energy without relying entirely on the aerobic system, given that basketball is characterised by high-intensity, intermittent exertion and rapid, explosive movements on the court.

Measurement of blood lactate concentration is often used as an indicator of anaerobic energy production via anaerobic glucose breakdown. Lactate production by working muscles is a consequence rather than a cause, as the anaerobic breakdown of glycogen produces pyruvic acid, which is converted to lactate due to the high availability of hydrogen ions ($+H$) that bind to pyruvic acid, converting it into lactic acid, thereby increasing blood acidity and lowering blood pH.

As glucose (sugar) is broken down in the body to produce energy, lactic acid is produced as a by-product; when the rate of glucose breakdown increases rapidly as a result of high-intensity physical exertion, blood lactic acid concentrations rise. This allows the body to sustain energy production for a longer period, even under conditions of oxygen deprivation. (Soultanakis et al., 2012).

According to scientific studies, the lactate concentration during a basketball match ranges between (4–7 mmol); a study by Rodriguez-Alonso et al. (2023) found the concentration to be (6.60 ± 1.22) mmol, whilst a study by Dragonea et al. (2019) (6.5 ± 1.27) millimoles, a study by (Gomes de Araujo et al., 2014) (5.2 ± 2.0), and a study by (Ben Abdelkrim et al., 2007) (6.22 ± 1.34) millimoles.

The fact that lactate concentrations in this study reached very high levels is because the aforementioned studies measured lactate either at the end of the match or between quarters – that is, during rest periods that could reduce its concentration, whereas the present study measured lactate after the completion of a basketball-simulated physical exertion, which was performed at high intensity and lasted no more than 2.5 minutes. This is consistent with the study by Figueira et al., (2021), in which lactate concentration reached



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(13.02 ± 2.28) during a physical exercise specific to basketball players, consisting of running (10×30 metres).

As for the increased perceived exertion, this indicates high-intensity physical exertion, which is consistent with what was mentioned earlier regarding the increased heart rate and concentration of lactic acid in the blood.

Conclusions

The basketball-simulated exercise test protocol is suitable for inducing fatigue in basketball players

- Fatigue indicators—namely heart rate, lactate concentration and perceived exertion—showed high reliability, indicating that the protocol is suitable for inducing fatigue.
 - The fatigue indicators—heart rate, lactate concentration and perceived exertion—remained consistently high, indicating that the protocol is suitable for inducing fatigue.
- To conduct more extensive studies using anaerobic capacity measures, such as the countermovement jump test, to assess the onset of muscle fatigue.
- To conduct more extensive studies using aerobic capacity measures ($\text{VO}_2 \text{ max}$) to assess the onset of muscle fatigue.



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