Original Article

Validity and reliability of fatigue manifestation during basketball game-based drill

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ABSTRACT

The quality of specific endurance preparedness could be verified by decrease of performance due to fatigue manifestation at the end of each quarter. The aim of this study was to determine validity and reliability of fatigue manifestation of basketball players during last three minutes of each quarter during game-based drill. Total of 86 male basketball players participated in this study. Every participant was monitored by the Sage Analytics to find activity demands during a game-based drill. One-way analysis of variance and reliability indexes were calculated. According to validity analysis, significantly growing total distance (F = 11.04; p = .001; η^2_p = .18) and descending precent of distance decrement (F = 5.46; p = .005; η^2_p = .11), and fatigue index (F = 14.07; p = .001; η^2_p = .28) with increased level of performance and at the same time growing total distance and descending precent of distance decrement for backcourt players. The reliability analysis showed that TD (F = 20.60; p = .001; η^2_p = .17) and precent of distance decrement (F = 5.80; p = .018, η^2_p = .05) are reliable instrument to express fatigue during game-based drill simulating match workload. The values of ICC were found very high inter-rater reliability for distance decrement (ICC = .818), high for total distance (ICC = .695). Total distance and distance decrement are valid and reliable instruments to express fatigue during game-based drill simulating match workload.

Keywords: Performance analysis of sport; Workload; Distance covered; Fatigue.

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INTRODUCTION

Basketball is intermittent, court-based sport (Stojanović et al., 2018) comprised of repeated high intensity movements such as change of direction, accelerations and decelerations, shuffling, sprinting, and jumping interspersed with periods of low to moderate intensity activity to recover (Edwards et al., 2018). Modern basketball training brings a greater integration of technology for player monitoring during training or match-play (Hulka, Strniste, & Hruby, 2022). According to Akubat, Barrett and Abt (2014) these modern technologies are used to identify external demands and internal responses to determine player's readiness to training or match and identifying fatigue during match-play.

Limitations to understanding fatigue may have arisen in part from the belief that manifestations of fatigue obtained using a reductionist approach or laboratory exercise models, relate directly to what happens in sport competition (Knicker, Renshaw, Oldham, & Cairns, 2011). Fatigue during match play is probably a complex phenomenon with a number of contributing factors (Bangsbo, Iaia, & Krustrup, 2007). Although many issues remain unresolved, proposed factors responsible for fatigue include limitations in energy supply (e.g. phosphocreatine content and.VO_2) and metabolic by-product accumulation like inorganic phosphate, H+ (Girard, Mendez-Villanueva, & Bishop, 2011).

Much research was made to identify fatigue during football match and was revised by Carling et al. (2008). In basketball Janeira and Maia (1998) found significant decreases in high-intensity activity and heart rate responses with game progression in elite junior and professional adult male basketball players. According to Ra et al. (2014) a common observation in many game situations is that decreases in both physical and mental performances occur toward the later stages of a match or his parts thus quarters in basketball. Similarly Khoramipour et al. (2021) recommended coaches to include increased awareness of the changing physical demands across quarters and match time flowed. Carling et al. (2008) and Bangsbo et al. (2007) found that fatigue demonstrated by decreasing performance seems to occur towards the ends of periods of matches and can lead to a win or loss of the match. Ben Abdelkrim, El Fazaa and El Ati (2007) found reduced performance occurs during the second and fourth quarters for players in all playing positions. Finally, Hulka et al. (2022) found fatigue manifestation during the last three minutes of the quarter during game-based drill which simulated basketball match. Fatigue was expressed in the decline of activity demands mainly decrease of distance covered and shift the relative time to less intensive activity zones from moderate and high intensity zones. Other variables (e.g. accelerations, decelerations, heart rate) were not changed due to fatigue, thanks to the pacing. When considered the endurance is the ability of players to resist fatigue, it means to keep the intensity of activity demands during the whole match for basketball players. We suppose that quality of specific endurance preparedness could be verified by decline rate of measured fatigue manifestations. This decline can be expressed as fatigue index according to McGawley and Bishop (2006). Therefore the aim of this study was to determine validity and reliability of fatigue manifestation of basketball players during game-based drill.

METHODS

Procedures

A between- and within-subjects observational study design was used to assess the construct validity and reliability fatigue index during game-based drill. The study was conducted over a three-week period. During the first session, participants were familiarized with wearing the Sage sensor and rules of game-based drill. To determine reliability, second and third session was used to apply game-based drill. To determine validity, amateur, semi-professional, and professional players were compared and backcourt (point guards and shooting guards) and frontcourt players (small forwards, power forwards, and centres) were compared with precondition that backcourt players underwent greater intermittent demands and were more fatigue resistance than frontcourt (Ben Abdelkrim et al., 2007). All monitored sessions took place on Mondays, in the afternoon, with rest period of 72 hour from the last practice. Each session started with a 20-min standardized warm-up consisting of moderate-intensity jogging, static and dynamic stretching, and accelerative running bouts. Each participant completed 4 x 10-min game-based drill according to Hulka et al. (2022), with a 5-min half-time break and 2-minute interquarter breaks. Scores were annulled at the beginning of each quarter, to ensure equal psychological (e.g. motivation) and tactical access (e.g. playing pace) to all periods. Free throws were not executed, and coaches did not have any time out to ensure the same playing time in every quarter and part of quarter. Coaches were instructed to maintain motivational, technical, and tactical instructions as during the official matches as well as players were instructed to play at their best as they would during a competition. HR response and activity demands were analysed separately across all quarters and the last 3-min of each quarter.

Participants

Twenty semi-professional and professional male basketball players (age = 24.2 ± 3.2 years; height = 190.7 ± 16.6 cm; body mass = 88.2 ± 20.1 kg) competing in the highest and second highest competitive level in Czech Republic volunteered to participate in reliability study. Twenty-five professionals (age = 24.9 ± 6.3 years; height = 190.3 ± 16.4 cm; body mass = 90.6 ± 22.1 kg), thirty semi-professional players (age = 25.1 ± 7.1 years; height = 189.6 ± 17.5 cm; body mass = 92.1 ± 24.8 kg) and thirty-one amateur players (age = 26.1 ± 9.1 years; height = 186.0 ± 21.1 cm; body mass = 96.0 ± 23.1 kg) participated on validity study. All players were classified as backcourt (n = 49; age = 24.9 ± 6.8 years; height = 188.1 ± 12.8 cm; body mass = 88.2 ± 14.1 kg) and frontcourt (n = 37; age = 24.7 ± 6.2 years; height = 196.1 ± 10.1 cm; body mass = 97.2 ± 17.6 kg) playing positions according to Scanlan, Tucker and Dalbo (2014).

All participants have at least ten years of experience. Professional and semi-professional participants trained at least five times a week with their teams with a match every weekend. Amateur participants trained at least three times a week with their teams with two matches every second weekend. Only participants free from injury and medical difficulties were included in the study. Participants were informed about the aims of the study including any risks, discomforts, benefits and provided written informed consent (by parents if under 18 years of age). The study was approved by institutional ethic committee (6/2022) which followed the Declaration of Helsinki.

Measures

Sage Analytics was used to measure distance covered. Sage Analytics is building dependent real time local positioning system based on UWB technology (Hulka, Strniste, & Prycl, 2020). The whole system work with TDOA-Based Algorithms. Whole system consists of tags, six fix-location base stations (anchors), server and Sewio platform. The tags are placed on athletes' upper back, between their shoulder blades. Four anchors are mounted in near each corner of the gym on side walls 18 m far from basketball midline and 2.7 m high, other two anchors are mounted on side walls at 9 m far from basketball middle line at a height of 2.7 m. The side walls are 2.5 m far from basketball side-lines. Anchors receive the signal from each tag, transmit the information through the Ethernet connection to a server, results are then processed and managed by Sewio platform. Raw data from Sage Analytics were exported into Microsoft Excel (v16.35; Microsoft Corporation; Redmond, WA, USA) to calculate total distance covered during each quarter and during last three minutes of each quarter. According to Hulka et al. (2020) showed coefficient of variation from 1.91 to 3.49 % and standard error of measurement from 0.07 to 0.12 m.

The fatigue manifestation was expressed by Total distance (TD), as TD = $\sum_{i=1}^{4} Dist_i$, where *Dist$_i$* was distance covered during las three minutes of each quarter. Then by Distance decrement (%D_{dec}) calculated according to Rampinini et al. (2009) as $\%D_{dec} = 100 * (1 - (\sum_{i=1}^{4} Dist_i / 4 * Dist_{best}))$, where *Dist$_i$* was distance covered during las three minutes of each quarter and *Dist$_{best}$* was the longest distance covered during las three minutes, and by Fatigue index (%FI) according to McGawley and Bishop (2006) *as % FI = 100* ((Dist$_{best}$ – Dist$_{worst}$)/Dist$_{best}$).*

Analysis
All data analyses were done using IBM SPSS software (version 25, IBM, Armonk, NY, USA) with alpha ≤ .05. Mean and SD were calculated for each outcome measure. Normality and homogeneity of all data was verified with the Kolmogorov-Smirnov and Levene's tests.

The intra-ratter reliability was expressed absolutely by Standard error of measurement (SEM) as an assessment involves calculating the variability in measurements of the same individual, i.e. the variance within subjects, which is referred to as error variance (Beckerman et al., 2001), and Bland-Altmann limits of Agreement (LoA) according to (Hopkins, 2000) as SEM = s*$\sqrt{(1 - \text{ICC})}$, where *s* was standard deviation of the sample and ICC is the calculated intraclass coefficient of correlation (the unbiased error), and LoA = ± 1.96*S_{diff} , where S_{diif} is standard deviation of difference. SEM was interpreted as a smallest real difference, thus the smallest measurement change, that can be interpreted as a real difference. Inter-rater reliability was expressed by relative values (ICC) and absolute values (typical error expressed as % CV and 95% Confidence Intervals). CV was calculated as standard deviation of difference divided by mean and multiplied by 100 (Atkinson & Nevill, 1998). Construct validity of fatigue manifestation was determined by comparison of fatigue manifestation over three performance levels and two playing positions by one-way ANOVA. When a significant effect of performance level was observed, the pairwise comparisons were examined using Tukey post hoc tests. Partial eta-squared (η^2_p) was utilized as a measure of effect size for each ANOVA, and values were interpreted as small effect (η^2_p < 0.04), medium effect (0.06 < η^2_p < 0.14), and large effect (η^2_p > 0.14). Statistical significance was set at p ≤ .05. ICC values were interpreted according to Hopkins (2007) as low = .1 – .30; moderate = .31 – .50; high = .51 – .70; very high = .71 – .90; nearly perfect = .9 – .99; and perfect = 1.0.

RESULTS

Twenty semi-professional and professional male basketball players performed two independent measurements during game-based drill to determine reliability of fatigue manifestation and eighty-six male basketball players performed one measurement during game-based drill to determine construct validity. Table 1 shows the results of validity measurement of TD, %D_{dec} and %FI. Table 2 shows the results of validity measurement expressed by SEM, %CV, Loa, 95%CI.

Validity analysis
The results of validity analysis are presented in Table 1. The influence of performance level to fatigue manifestation was found for total distance (F = 11.04; *p* = .001; η^2_p = .18). According to post-hoc test the amateur players covered significantly less distance than semi-professionals (r = .002) and professional players (r = .001). Similar results of ANOVA were found for %D_{dec} (F = 5.46; *p* = .005; η^2_p = .11), when amateur players reached larger distance decrement than professionals (r = .005). %FI was significantly different for performance levels (F = 14.07; *p* = .001; η^2_p = .28), when amateur players reached larger %FI than semi-professionals (r = .001) and professionals (r = .001). When compared frontcourt and backcourt

players we found out significant differences in total distance (F = 20.60; *p* = .001; η^2_p = .17) and distance decrement (F = 5.80; *p* = .018, η^2_p = .05), but not in fatigue index (F = 1.25; *p* = .26; η^2_p = .01).

Table 1. Validity analysis.

	TD	**% D_{dec}**	**% FI**
Amateur	1062.15 ± 176.68	14.75 ± 4.91	32.81 ± 9.46
Semi-Professional	1204.51 ± 172.71$^+$	12.37 ± 4.32	23.92 ± 7.84$^+$
Professional	1216.88 ± 111.11$^+$	8.15 ± 4.20$^+$	19.69 ± 9.37$^+$
Frontcourt	1030.92 ± 100.04*	14.07 ± 6.51*	46.2 ± 21.28
Backcourt	1198.41 ± 131.63	12.11 ± 4.06	39.03 ± 13.71

*Note. TD-total distance, %D_{dec} – distance decrement, %FI- Fatigue index, *-Significantly different from backcourt; $^+$Significantly different from amateur players; $^\#$Significantly different from Semi-professional.*

Reliability analysis

The players covered 1194.58 ± 161.67 m during last three minutes of each quarter during which percent of distance decrement was 10.55 ± 2.12 % and fatigue index was 33.72 ± 9.31 %. According to the one-way ANOVA findings, within a five percent significance, there were no statistically significant differences for TD (F = 0.41; *p* = .53), % D_{dec} (F = 0.65; *p* = .43), and %FI (F = 0.01; *p* = .94) between the results obtained from the first and second measurements. The values of ICC were found very high inter-rater reliability for %D_{dec} (ICC = .818), high for TD (ICC = .695), and moderate inter-rater reliability for %FI (ICC = .497). The SEM values for TD was 79.80 m, which represented 6.7 % of TD, for %D_{dec} was SEM = 0.79 % (7.4 % of mean value), and for %FI was SEM = 3.14 % (9.3 % of mean value). The LoA was ±283.22 m for TD, ±3.65 % for %D_{dec}, and ±11.35 % for %FI. The results of reliability analysis are presented in Table 2.

Table 2. Reliability analysis.

	Td (m)	**%D_{dec}**	**%FI**
Mean ± SD	1194.58 ± 161.67	10.55 ± 2.12	33.72 ± 9.31
ICC	.695 (.31 to .89) *p* = .008	.818 (.56 to .90) *p* = .002	.497 (.33 to .70) *p* = .19
SEM	79.80	0.79	3.14
CV (%)	10.53	15.65	17.07
B-A LoA	283.22	3.65	11.35
Lower CI	858.28	8.29	22.96
Higher CI	1085.13	12.08	41.20

Note. TD-total distance, %D_{dec} – distance decrement, %FI- Fatigue index, ICC- Intraclass coefficient of correlation, SEM- standard error of measurement, CV – coefficient of variation, B-A LOA – Bland-Altman limits of agreement.

DISCUSSION

Reliability is a theoretical concept that is used to describe the quality of a measurement instrument. The knowledge of various sources of measurement errors helps individuals to better understand the collected data and the overall analysed phenomenon (Hulka, Cuberek, & Svoboda, 2014). This study investigated the validity and reliability of fatigue manifestation of male basketball players during game-based drill expressed by total distance, distance decrement, and fatigue index in last three minutes of each quarter during basketball game-based drill, which simulated match workload.

According to validity analysis, significantly growing TD and descending $\%D_{dec}$, and %FI with increased level of performance and at the same time growing TD and descending $\%D_{dec}$ for backcourt players. The reliability analysis showed that TD and $\%D_{dec}$ are reliable instrument to express fatigue of players during game-based drill simulating match workload.

According to results the measurement of fatigue expressed by TD, $\%D_{dec}$, and %FI was not burdened by systematic bias, because between-sessions differences were not significant. The high ICC values were interpreted as significantly high for TD, very high for $\%D_{dec}$, and only moderate for %FI. These results showed very high intra-ratter reliability of $\%D_{dec}$ and high intra-ratter reliability of TD. The within-subject variance showed similar trend, when the smallest variability in measurement of the same individual showed $\%D_{dec}$ = 0.79 % and TD = 79.80 m. The coaches and researchers in future studies can calculate with smallest real difference 3.65 % for $\%D_{dec}$, and 79.80 m for TD. Due to these results, it seems that TD and $\%D_{dec}$ are reliable instruments to express fatigue of players during game-based drill simulating match workload. Larger interindividual differences in the CV calculation in our study were probably due to situational variability during game-based drill.

Construct validity refers to the level of which a protocol measures a hypothetical construct and is usually by relating the test results to some behaviour (Paul & Nassis, 2015). Construct validity is commonly established by testing differences among groups of participants of different competitive levels (Brini et al., 2021). The results of ANOVA Analysis showed that performance level influence the size of fatigue manifestation (performance decline) during last three minutes. This fact can be caused by higher training weekly load and more intensive work during training sessions. Similarly, Brini et al. (2021) explained that higher level players are better than level players, as we know they have better aerobic fitness, strength, and a better training status.

When comparing player positions frontcourt players covered less TD than backcourt players. During a match frontcourt players spent more time in recovery but were involved in less high-intensity activity than backcourt players (Ben Abdelkrim et al., 2007) because of spending time close to the basket and are heavier and taller than frontcourt players (Sallet, Perrier, Ferret, Vitelli, & Baverel, 2005). When the smallest real difference was established, the difference among amateur and semi-professional and professional players was not caused by error measurement, because SEM is smaller than level differences. But we found smaller differences between semi-professional and professional players. This could be explained that both levels have similar number of training sessions and conditioning coaches in contrast with amateur level.

As a limit of the study, we consider that results may not be representative of teams of different ages, gender and playing levels. Concurrently for deeper usage of results to make a more individualised training process more detailed post differences should be considered. Equally score and tactical aspects were not reflected.

CONCLUSION

The results showed the sensitivity of total distance and percent of distance decrement during last three minutes of each quarter of game-based drill to playing position and performance level. Due to reliability analysis results the fatigue manifestation expressed by total distance covered during last three minutes of each quarter and percent of its decrement during basketball game-based drill are suitable and reliable instruments to express fatigue of players during game-based drill simulating match workload. Both parameters could be used in research considering calculated errors of measurement.

AUTHOR CONTRIBUTIONS

KH, MS, and MH conceived and designed the experiments; KH, MS and JB performed the experiments; KH and MH analysed the data; KH, MS, MH and JB wrote the paper and approve the final submission.

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DISCLOSURE STATEMENT

No potential conflict of interest were reported by the authors.

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