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COUNTERMOVEMENT JUMP AND T-AGILITY TEST, POSSIBLE INDICATORS OF ACCUMULATED FATIGUE IN YOUTH BASKETBALL PLAYERS?

Gabriel Maurente
Universidad de la Empresa (Uruguay)
alemaurente0529@gmail.com · http://orcid.org/0000-0002-6416-742X
Bernardo Chávez
Universidad de la Empresa (Uruguay)
nanincf@gmail.com · http://orcid.org/0000-0002-9419-6248
Andrés Parodi
Universidad de la Empresa (Uruguay)
andresparodi2005@yahoo.com · http://orcid.org/0000-0003-3498-352X

Abstract. Introduction: there is a growing interest in monitoring cumulative fatigue in sport. In this study we aimed to determine whether the Countermovement Jump test (CMJ) and the T-agility test (TaT) are possible indicators of cumulative fatigue in youth basketball players. Methods: 16 male players were divided into experimental (EXP) and control (CONT) groups. All of them performed physical and technical-tactical training with a frequency of 5 times a week, during four microcycles (MiC). During the 1st MiC, all participants trained with a low intensity load. Subsequently, the EXP group trained with progressively higher loads, ending with very high intensities; the CONT group maintained a low training intensity throughout the entire mesocycle. Before the intervention, and at the end of each MiC, all subjects were tested by CMJ and TaT. Results: in EXP, a decrease in performance was observed in both tests ($p \leq 0.05$), when comparing each evaluation with the previous one. In CONT, no loss of performance was observed in CMJ; as for TaT, only a reduction in performance ($p \leq 0.05$) was observed when comparing the evaluation at the end of the 4th MiC with the corresponding one at the end of the 3rd MiC. Additionally, a moderate ($r = -0.589$) and high ($r = 0.683$) correlation was established, respectively, between CMJ and TaT performance in relation to training intensity. Conclusions: these findings would indicate that both tests could be useful as a tool for monitoring accumulated fatigue during a training mesocycle in young basketball players.

Keywords: cumulative fatigue; youth basketball; CMJ; agility test T

SALTO CON CONTRAMOVIMIENTO Y TEST DE AGILIDAD T, ¿POSIBLES INDICADORES DE FATIGA ACUMULADA EN BALONCESTO JUVENIL?

Resumen. Introducción: existe creciente interés en controlar la fatiga acumulada en el deporte. En este trabajo se estudió el salto con contramovimiento (CMJ) y el Test de agilidad T (TaT), como posibles indicadores de fatiga acumulada en jugadores juveniles de baloncesto. Métodos: 16 jugadores masculinos fueron divididos en grupos: experimental (EXP) y control (CONT). Todos realizaron entrenamiento físico y técnico-táctico con una frecuencia de 5 veces semanales, durante cuatro microciclos (MiC). Durante el 1er MiC, todos los participantes entrenaron con una carga de poca intensidad. Subsecuentemente, el grupo EXP entrenó con cargas progresivamente más altas, finalizando con intensidades muy elevadas; el grupo CONT mantuvo una intensidad baja de entrenamiento durante todo el mesociclo. Antes de la intervención, y al finalizar cada MiC, todos los sujetos fueron testeados mediante CMJ y TaT. Resultados: en EXP se observó una pérdida de rendimiento en ambos test ($p < 0.05$), al comparar cada evaluación con la precedente. En CONT, no se observaron pérdidas de rendimiento en CMJ; en cuanto al TaT, únicamente se verificó una reducción en el rendimiento ($p < 0.05$) al comparar la evaluación al finalizar el 4º MiC con la correspondiente al finalizar el 3er MiC. Adicionalmente, se estableció una correlación moderada ($r = -0.589$) y alta ($r = 0.683$) respectivamente, entre el rendimiento en CMJ y TaT, con relación a la intensidad de entrenamiento. Conclusiones: estos hallazgos indicarían que ambos test podrían ser útiles como una herramienta de control de la fatiga acumulada, durante un mesociclo de entrenamiento en baloncesto juvenil.

Palabras clave: fatiga acumulada; baloncesto juvenil; CMJ; test de agilidad T

Introduction

The demands of competition in team sports, increased in recent years, have generated much interest in coaches, physical trainers, and athletes regarding fatigue control; this is due to its relationship with performance and increased risk of injury (Thorpe et al., 2017). In youth categories, it is also necessary to consider the prospective development of players, which makes the control of loads, and the fatigue caused by it, even more relevant in this population (Balyi et al., 2013).

In this context, it is of particular interest to have evaluation strategies that allow estimating the internal load to which athletes are subjected, as well as the degree of fatigue (acute or accumulated) that they are experiencing. Such strategies, in addition to being valid, should ideally be practical, non-invasive, and economical, particularly for their application in sports institutions with limited human and financial resources.

One of the tools that meets these conditions is the modified Borg (1982) rating of perceived exertion scale (RPE). Based on this scale, Foster et al. (1996, 2001) proposed a method for quantifying session load as an alternative to methods based on heart rate. This method is called *session rating of perceived exertion* (sRPE) and consists of multiplying the volume of the session (in minutes) by the RPE indicated by the athlete for the whole session (according to the aforementioned scale). In this way, components of the internal and external load experienced by the player are represented in a single value, which is expressed in arbitrary units (AU).

Considering the challenges in measuring the various types of stress to which subjects are exposed during training, such a method largely represents a legitimate strategy, validating its use in different team sports, including basketball (Moreira et al., 2012; Singh et al., 2007; Wallace et al., 2014).

A strong correlation has also been observed between sRPE values with physiological variables associated with load intensity, such as heart rate, the latter being a representative measure of intensity (Manzi et al., 2010; Montgomery et al., 2010). Given the complex interplay of factors that contribute to individual perception of physical exertion, a multidimensional perspective is necessary to address this process (Tenenbaum and Hutchinson, 2007).

The sRPE strategy further represents a useful and practical strategy for estimating and monitoring cumulative fatigue throughout a microcycle (MiC), mesocycle, or even macrocycle of training (Haddad et al., 2017). In agreement with Clarke et al. (2013), this method could help optimize physical development while minimizing the risk of overtraining, injury, and illness; in part by allowing greater insight into individual response to training loads.

Regarding fatigue estimation, one of the widely used tools is the determination of Countermovement Jump (CMJ). This test has been considered one of the most valid for monitoring neuromuscular fatigue in different sports disciplines (Miras, 2020), in addition to having a high reliability (Gathercole et al., 2015b). In cyclic sports, *almost perfect* correlations were verified between altitude loss and blood lactate and ammonium concentration ($r = 0.95$ and $r = 0.94$ respectively) after 40m sprint efforts (Jiménez-Reyes et al., 2016).

In team sports, a progressive loss of performance has been observed in youth basketball players during and one to seven minutes after the competition, with losses of up to 19.8% in maximum height (San Román et al., 2010). An immediate post-competition performance loss of 7.4% in maximum height was also verified in elite handball players (Póvoas et al., 2014). It has been established that the sensitivity of CMJ to detect alterations in neuromuscular function (and concomitantly, neuromuscular fatigue) remains prolonged in time, with performance losses being detected even 72h after intense effort (Gathercole et al., 2015b). For this reason, variations in the performance achieved in CMJ can be used as a control tool, for the adjustment of training loads, and the eventual increase of sports performance (Loturco et al., 2017). Additionally, in the case of basketball, this test presents a high specificity due to the importance of vertical jump as a sporting gesture for this particular discipline. On the other hand, regarding the use of the CMJ for monitoring accumulated fatigue after several microcycles of training, the studies that have been conducted are scarce, and the discrepancies in their results do not allow us to clearly establish the possible usefulness of this test for this purpose (Freitas et al., 2014; Gathercole et al., 2015a). Additionally, to the best of our knowledge, this analysis has not been performed in a population of youth basketball players.

Another quality that contributes to success in collective sports in general, and in basketball in particular, is agility; understood as the ability to quickly change direction and speed (Sekulic et al., 2017; Spiteri et al., 2014). This skill has been recognized as one of the most important for this sport in which players make sudden changes of direction and speed every few seconds, and in a relatively small area of play (Abdelkrim et al., 2010; Boone and Bourgois, 2013; Scanlan et al., 2014). The T-agility test (TaT) is considered one of the most appropriate tests to estimate this skill in basketball because it uses many of the basic movements performed during a game, particularly in defensive maneuvers (Chaouachi et al., 2009; Stojanovic et al., 2018). Despite the potential usefulness of the use of this test as an indirect indicator of fatigue (acute or accumulated) in youth basketball, given the high neuromuscular component involved in its execution, to the best of our knowledge, its use for this purpose has not been analyzed.

In the present work, we try to determine the possible relationship between the accumulated fatigue in a training mesocycle and the performance in the CMJ and TaT tests. The purpose is to provide coaches of collective sports, and particularly youth basketball, with additional practical tools for the control of such fatigue, facilitating the consequent and necessary adjustment of training loads.

Method

Subjects

By means of convenience sampling, 18 players were selected from a youth federated team of the city of Montevideo, belonging to the Uruguayan Basketball Federation (FUBB). The subjects resumed their usual training coinciding with the beginning of the experimental intervention, after 2 months of inactivity due to the restrictions imposed by the COVID-19 pandemic. Prior to the intervention, all participants were orally informed of the characteristics and objectives of the study, after which they read and signed an informed consent form.

The following inclusion criteria were taken into account: i) have a current medical record; ii) have at least two years of experience as a federated basketball player; iii) not present any type of injury or pathology that could affect the results of the study; iv) not be consuming drugs that could affect sports performance; v) not be a smoker; vi) not engage in any other type of training or sport outside the one established in the experimental intervention.

Using convenience sampling, subjects were ~~non-randomly~~ divided into two groups: experimental (EXP) (n = 8; age = 17.8 ± 0.9 years; BMI =23.9 kg/m^2) and control (CONT) (n = 8; age = 17.8 ± 0.9 years; BMI = 24.3 kg/m^2). Both groups competed at a similar level but trained at different times. This allowed, from an organizational point of view, to adequately separate and control the different loads applied. Considering a significance level of p=0.05, there are no differences between the two groups in terms of age (p=0.87) and BMI (p=0.59).

Procedures

The evaluations and experimental intervention were carried out in the month of June 2021; during this mesocycle, the players were in a preseason period and did not participate in any competition or friendly match with other teams. All players attended at least 85% of the training sessions planned during the intervention mesocycle.

Evaluations

On the Saturday prior to the beginning of the experimental intervention, the following variables were measured in all athletes: i) Height and mass, for BMI determination. Height was measured using a SECA 213 stadiometer (SECA, Germany), with a precision of 1mm; mass was determined using a SAGAS scale (TPR - 200, Peru) with a precision of 100g. In both cases the technique described by the International *Society for the Advancement of Kinanthropometry* (ISAK) was used; ii) Maximum height in CMJ. A DMJUMP®2.5 jumping platform (DMJump, Chile) was used for this purpose. Without previous warm-up exercises, the subjects performed three jumps, with a two-minute passive pause between them. From an upright position and without taking their hands off the waist, the players performed a rapid downward movement until reaching a 90º knee flexion, followed immediately by a maximum upward effort to reach the maximum height, according to the protocol described by Bosco et al. (1983). For the purposes of this work, the best attempt of the three was taken as valid; iii) TaT performance. A version of the protocol described by Semenick (1990) was used, modifying the units of measurement from yards to meters, similar to that described by Raya et al. (2013). From the starting position (A), subjects moved at maximum speed to the central cone (B); then by lateral displacement to the cone located 5m to the right (C); then with lateral displacement to the cone (D), located 10m to the left; they returned with lateral displacement to the central cone (B); finally running backwards until crossing the starting line (A) (Figure 1). This test was carried out on the players' regular training field, *after* the CMJ tests had been performed. The players also wore their usual training shoes. A CASIO manual stopwatch, model IP2810, was used to determine the time. Prior to the execution, the players performed a standardized warm-up of 20 minutes, which included joint mobility, dynamic stretching, jumps, jogging, and accelerations. Only one attempt was made per athlete.

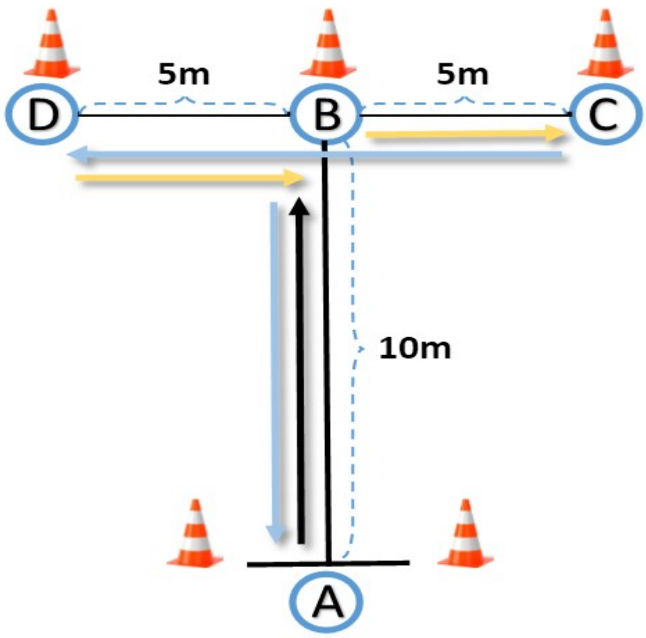

Figure 1. Schematic representation of the T-agility test.

All tests were conducted during the players' regular training schedule. They were carried out at the facilities of the corresponding club, which has a closed court.

On Saturdays, after each of the four MiCs during the intervention, the CMJ and TaT tests were repeated under exactly the same conditions described above. The players were insisted on the importance of adequate rest, the night before each of the evaluation instances. Additionally, and although it was not controlled, they were asked not to modify their eating habits during the time the study lasted. The research was carried out respecting the ethical principles established in the Declaration of Helsinki (Rev.2008).

Experimental intervention

During the intervention mesocycle, both EXP and CONT subjects performed 5 sessions per week. All training sessions began with a standardized 15-minute warm-up based on: jogging, technical skills (dribbling the ball and layups), full-court offensive drills (e.g., 3-on-0; 3-on-2; and 3-on-3 drills), and dynamic stretching exercises.

On Monday, Tuesday, Thursday, and Friday, each of the sessions included, in addition to the warm-up and cool-down, physical preparation exercises (approximately 60 minutes) and then technical-tactical training (approximately 60 minutes). On Wednesdays, the players only undertook technical-tactical training, lasting approximately 120 minutes. All training sessions were directed and/or supervised by two of the authors of this study (A.M and B.C.).

Both in the case of technical-tactical training and physical training, the activities performed were similar in both groups, but the training loads were differentiated considering their sRPE. In the EXP group, the components of the load (particularly in terms of intensity and density) were planned, and then adjusted during the course of the intervention, so as to achieve an increase in the average weekly intensity (in terms of AU) that was increasing by about 20 to 25%, compared to the immediately preceding MiC.

In agreement with Aoki et al. (2017), the increase in the intensity of the training session is mainly due to the increase in actions that require changes of direction, accelerations and decelerations, sprints and other specific actions related to the specificity of the sport. Based on this, the training sessions of the EXP group were planned with a higher volume of work, particularly of exercises involving these types of high-intensity actions.

The technical-tactical training consisted primarily of unopposed drills (2 vs 0 to 5 vs 0) focused on offensive aspects; tactical drills with opposition (1 vs 1 to 4 vs 4) focused on defensive aspects; and technical drills (e.g., shooting, passing). In the EXP group, intensity and volume were constantly manipulated using responses and daily monitoring using the sRPE. Such manipulation included changes in the relationship between work and recovery within and between drills, varying the number of players performing full-court scrimmage drills, as well as strategic change in rules (among others, varying the size of the playing field, number of players, play with or without free throws, and/or inclusion of repeated sprinting after a given game situation).

In addition, an increase in the load and intensity of the overload training sessions was planned. In this way, we sought to enhance the fatigue processes in the players of this group throughout the training mesocycle.

On the other hand, the training loads in the CONT group sessions were adjusted in such a way that the average weekly intensity (in terms of AU) was similar, during the entire mesocycle, to the intensity applied to the EXP group during the first MiC, and remained constant throughout the intervention. In this way, it was ensured that the low average intensity applied to the athletes in the CONT group did not generate cumulative fatigue effects throughout the entire training mesocycle.

The planning of the physical training loads throughout the intervention mesocycle, and the load control used during the intervention for the EXP and CONT groups, can be seen in Table 1.

All sessions were conducted in the same training center, with an ambient temperature ranging from 11° to 20° and humidity between 78% and 82% for the duration of the intervention. Regular verbal encouragement from the head trainer and staff members was allowed during the sessions.

Table 1
Planning of physical training loads during the intervention mesocycle

	EXP	CONT
	Microcycle 1	
Monday	Push MMII 3 x 8-10 x 60-70% 1RM; Pull MMSS 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m	Push MMII 3 x 8-10 x 60-70% 1RM; Pull MMSS 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Tuesday	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Thursday	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m	Push MMII 3 x 8-10 x 60-70% 1RM; Pull MMSS 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Friday	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70mts	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
	Microcycle 2	
Monday	Push MMII 4 x 8-10 x 60-70% 1RM; Pull MMSS 4 x 8 x 60-70% 1RM Sprint 15" X 15" passive pause Run 2 x 7min x 70m	Push MMII 3 x 8-10 x 60-70% 1RM; Pull MMSS 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Tuesday	Push MMSS 4 x 8-10 x 60-70% 1RM; Pull MMII 4 x 8 x 60-70% 1RM Sprint 10" x 20" passive pause Run 3x 6min x 70m	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8reps x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Thursday	Push MMII 4 x 8-10 x 60-70% 1RM; Pull MMSS 4 x 8 x 60-70% 1RM Sprint 15" X 15" passive pause Run 2 x 7min x 70m	Push MMII 3 x 8-10 x 60-70% 1RM; Pull MMSS 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Friday	Push MMSS 4 x 8-10 x 60-70% 1RM; Pull MMII 4 x 8 x 60-70% 1RM Sprint 10" x 20" passive pause Run 3x 6min x 70m	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
	Microcycle 3	
Monday	Push MMII 5x 8-10 x 60-70% 1RM; Pull MMSS 5 x 8 x 60-70% 1RM Sprint 15 "X15 "X15 "passive pause Race 2 x 8 min - 35m round trip	Push MMII 3 x 8-10 x 60-70% 1RM; Pull MMSS 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Tuesday	Push MMSS 5 x 8-10 x 60-70% 1RM; Pull MMII 5 x 8 x 60-70% 1RM Sprint 10" x 10" passive pause Run 4 x 4 min 60m	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Thursday	Push MMII 5x 8-10 x 60-70% 1RM; Pull MMSS 5 x 8 x 60-70% 1RM	Push MMII 3 x 8-10 x 60-70% 1RM; Pull MMSS 3 x 8 x 60-70% 1RM

	Sprint 15 "X15 "X15 "passive pause Race 2 x 8 min- 35 mts round trip	Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Friday	Push MMSS 5 x 8-10 x 60-70% 1RM; Pull MMII 5 x 8 x 60-70% 1RM Sprint 10" x 10" passive pause Run 4 x 4 min x 60m	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
	Microcycle 4	
Monday	Push MMII 6 x 8-10 x 60-70% 1RM; Pull MMSS 3 x 8 x 60-70% 1RM Sprint 10 "x10" passive pause Run 4 x 6 min x 55m	Push MMII 3 x 8-10 x 60-70% 1RM; Pull MMSS 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Tuesday	Push MMSS 6 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 5" x 5" passive pause Run 4 x 4 min 40m	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Thursday	Push MMII 6 x 8-10reps x 60-70% 1RM; Pull MMSS 3 x 8reps x 60-70% 1RM Sprint 10 "X10" passive pause Run 4 x 6 min x 55m	Push MMII 3 x 8-10reps x 60-70% 1RM; Pull MMSS 3 x 8reps x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m
Friday	Push MMSS 6 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 5" x 5" passive pause Run 4 x 4 min x 40m	Push MMSS 3 x 8-10 x 60-70% 1RM; Pull MMII 3 x 8 x 60-70% 1RM Sprint 15" x 30" passive pause Run 2 x 6min x 70m

Note: training loads are expressed as sets - repetitions - intensity. Abbreviations: EXP = experimental group; CONT = control group; RM = repetition maximum; MMII = lower limbs; MMSS = upper limbs.

Quantification of session AUs

After the end of the session, each player was asked to mention the perceived intensity of effort for the entire session, using Borg's (1982) modified RPE scale. Following the procedures used by Lupo et al. (2017), who worked with a population similar to that of the present study, this value was collected approximately 30 minutes after the end of each session. This period of time is considered necessary to prevent the subjects from being influenced by the intensity of the training loads applied during the last minutes of the session. In this way, the player can rate the entire session with a greater "perspective," thus, decreasing the bias.

The value obtained was multiplied by the duration of the session (in minutes) to obtain a value in AU. With this data, the average training load of the microcycle was obtained for each participant.

The duration of each session was recorded individually, including intra- and inter-exercise rest periods but excluding the duration of pre-conditioning or cool-down exercises. All players were familiar with the use of the modified RPE because they had used it in previous training sessions; although this is the first time, they used it to estimate whole-session intensity (sRPE).

Statistical analysis of data

A basic descriptive analysis was made of the data obtained, expressed as mean ± standard deviation. The data from the evaluations prior to the experimental intervention for each group (EXP and CONT) were subjected to Student's t-test for independent data, after checking the assumptions of homogeneity of variance (using

Levene's test) and normality (using the Shapiro-Wilk test). If these assumptions were not verified, the Mann-Whitney-Wilcoxon u test was used.

The data obtained for both groups, in the successive CMJ and TaT evaluations, were analyzed by means of a one-factor repeated measures ANOVA test to establish possible differences between the observed means. If a statistically significant difference was found, a post-hoc test was performed to determine at which level or levels this difference was verified.

To determine the correlation between the training load, the CMJ jump height and the time required in the TaT, the Pearson's r test was used, after determining normality by means of the Shapiro-Wilk test.

For all cases, a significance level $\alpha = 0.05$ was established. For statistical analysis, the free software JASP 0.16.1 (University of Amsterdam) was used.

Results

Characteristics of the pre-intervention sample

Table 2 shows the characteristics of the sample studied. Prior to the start of the intervention, there were no significant differences ($p > 0.05$) in the age, height, and mass of the participants.

Table 2
Characteristics of the pre-intervention sample

	EXP	CONT	p- value
Age (years)	17.8 ± 0.9	17.8 ± 0.9	-
Height (cm)	181,8 ± 8,9	182,8 ± 12,3	0.483^{+}
Mass (kg)	78,9 ± 12,7	81,3 ± 8,6	0.105*

Note: In all cases, a significance level of $\alpha = 0.05$ was established; $^{+}$ = Student's t for independent data; * = Mann-Whitney's u. Abbreviations: EXP = experimental group; CONT = control group.

Table 3 shows the results of the TaT and CMJ for the EXP and CONT groups, prior to the experimental intervention. There was no significant difference ($p > 0.05$) between the two groups in terms of performance in the first test mentioned. However, there was a significant difference ($p \leq 0.05$) between both groups in the CMJ performance in favor of the EXP group (39.7cm EXP vs 32.8cm CONT).

Table 1

Performance on the pre-intervention T-agility and CMJ tests.

	EXP	CONT	p- value
TaT (s)	8.2 ± 0.7	8.3 ± 1.2	0.629+
CMJ (cm)	39.7 ± 6.5	32.8 ± 3.7	0.021+

Note: In all cases a significance level of $\alpha = 0.05$ was established;+ = Student's t for independent data; * = Mann-Whitney test. Abbreviations: EXP = experimental; CONT = control; CMJ = *Countermovement Jump* test; TaT = T-agility test.

Training loads used

Table 4 shows the volume, sRPE, and average AU records for each session, individualized by MiC of training, for both groups. In the EXP group, from MiC 1, an increase in the average session load for that week (measured in AU) of 19.6% (micro 1 to 2), 26.6% (micro 2 to 3), and 12% (micro 3 to 4) is verified. In the CONT group, the differences in the loads applied week to week were -1.6% (micro 1 to 2), 0% (micro 2 to 3), and 0.5% (micro 3 to 4). In this last group, and in accordance with what was planned, there were no significant differences between the four training MiC (p > 0.05).

Table 4

Record volume, sRPE, and average AU per session for each training microcycle.

	EXP	CONT
	Microcycle 1	
Volume (min)	120 ± 0.0	
sRPE	4.9 ± 0.2	4.7 ± 0.3
AU	**594 ± 20.1**	**564 ± 34.5**
	Microcycle 2	
Volume (min)	120 ± 0.0	120 ± 0.0
sRPE	5,9 ± 0.2	4,6 ± 0.4
AU	**711 ± 25.1**	**555 ± 42.5**
	Microcycle 3	
Volume (min)	120 ± 0.0	120 ± 0.0
sRPE	7,5 ± 0.9	4,6 ± 0.4
AU	**900** ± 37.9	**555** ± 42.5
	Microcycle 4	
Volume (min)	120 ± 0.0	120 ± 0.0
sRPE	8,4 ± 0.4	4,6 ± 0.3
AU	**1008 ± 49.2**	**552 ± 39.1**

Note: Abbreviations: EXP = experimental group; CONT = control group; sRPE = subjective feeling of session effort; AU = arbitrary units.

CMJ test performance

Table 5 and Figure 2 present the results of the CMJ performance for the EXP and CONT groups, pre- and intra-intervention. In EXP, a systematic decrease in values is observed as the MiCs elapse. A significant difference in these results is also verified ($p \leq 0.05$) in the ANOVA test. Comparing the final value (at the end of MiC 4) with the pre-intervention value, a 16% decrease in jump height is verified. As for the CONT group, although a tendency to a decrease in performance is observed, it is less marked than for the EXP group, without showing a statistically significant difference ($p > 0.05$) between the results.

Table 2
Pre- and intra-intervention CMJ test results

	Initial	**Micro 1**	**Micro 2**	**Micro 3**	**Micro 4**	**p-value**
EXP	39.7 ± 6.5	37.9 ± 6.4	36.1 ± 6.0	34.8 ± 6.3	33.3 ± 6.3	< 0.001
CONT	32.8 ± 3.7	31.6 ± 3.8	32.2 ± 3.8	31.8 ± 3.7	30.3 ± 4.1	0.058*

Note: A one-factor repeated measures ANOVA test was used; in all cases a significance level of $\alpha = 0.05$ was established. * Greenhouse-Geisser correction was used since the data did not meet the assumption of sphericity. Initial = value prior to the intervention; Micro = value taken at the end of the corresponding microcycle. Abbreviations: CMJ = *Countermovement Jump* test.

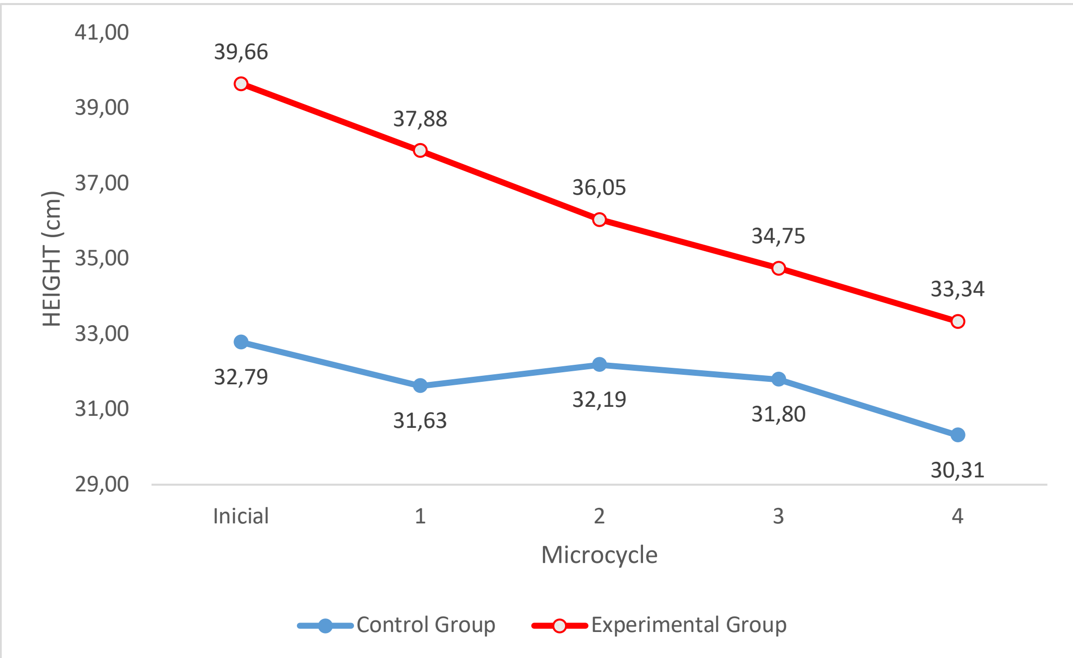

Figure 2. Performance in the CMJ test for the Experimental and Control groups.

Table 6 shows the Post hoc test performed on the EXP group. It shows that there is a statistically significant difference ($p \leq 0.05$) when comparing each of the MiCs considered.

Figure 3 shows the correlation between the average height reached in the CMJ and the average training load (AU) applied in the corresponding MiC session. A significant correlation ($p < 0.001$) of $r = -0.589$ was verified. The same following the classification of Goss-Sampson (2019) is interpreted as moderate ($0.4 < r \leq 0.6$).

Table 3
Post hoc comparison of CMJ test performance for the Experimental Group.

		Average difference (cm)	p-value
Initial	Micro 1	1.8 ± 0.4	< 0.001
	Micro 2	3.7 ± 0.4	< 0.001
	Micro 3	4.9 ± 0.4	< 0.001
	Micro 4	6.4 ± 0.4	< 0.001
Micro 1	Micro 2	1.8 ± 0.4	< 0.001
	Micro 3	3.1 ± 0.4	< 0.001
	Micro 4	4.5 ± 0.4	< 0.001
Micro 2	Micro 3	1.3 ± 0.4	0.005
	Micro 4	2.7 ± 0.4	< 0.001
Micro 3	Micro 4	1.4 ± 0.4	0.005

Note: The Holm-Bonferroni test was used. In all cases a significance level of $\alpha = 0.05$ was established. Initial = value prior to the experimental intervention; Micro = value taken at the end of the corresponding microcycle.

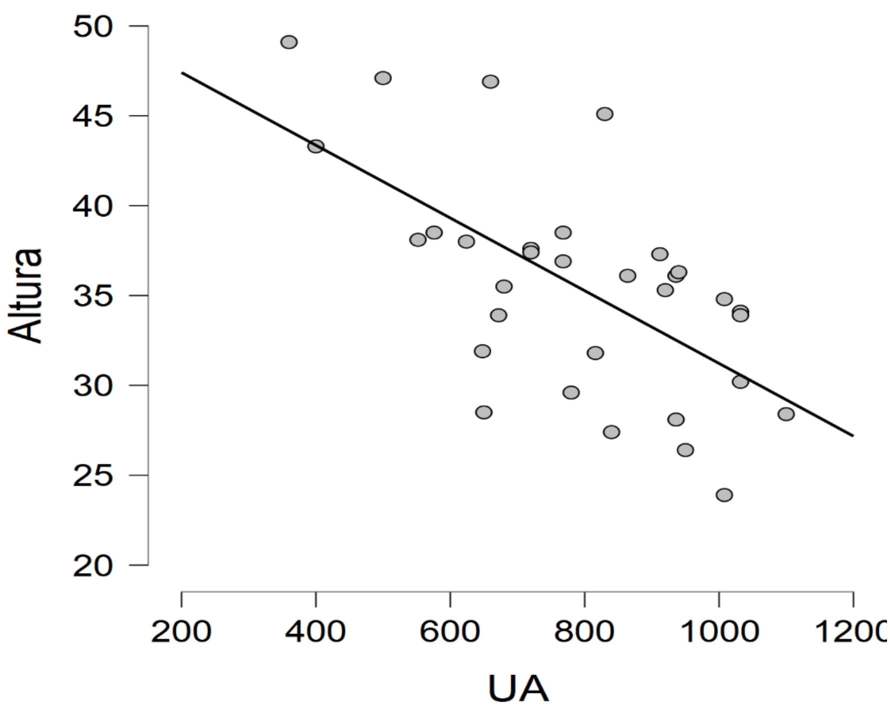

Figure 3. CMJ performance as a function of applied load.
Note: Only data from the EXP group were considered. AU = average training load of the session during a given microcycle.

Agility test performance T

Table 7 and Figure 4 show the results of TaT performance for the EXP and CONT groups. In both, a trend towards an increase in the time demanded for the completion of the test (i.e., a reduction in performance) is observed, more marked in the EXP group than in CONT. In both cases, a statistically significant difference ($p \leq 0.05$) was verified when comparing the results of the different evaluation instances by means of ANOVA test.

Table 4
Pre- and intra-intervention T-agility test results

	Initial	**Micro 1**	**Micro 2**	**Micro 3**	**Micro 4**	**p-value**
EXP	8.2 ± 0.7	8.4 ± 0.7	8.9 ± 0.8	10.1 ± 1.3	11.2 ± 1.5	< 0.001*
CONT	8.4 ± 1.3	8.3 ± 1.2	8.6 ± 1.1	8.7 ± 0.9	9.3 ± 0.9	0.003*

Note: A one-factor repeated measures ANOVA test was used; in all cases a significance level of $\alpha = 0.05$ was established. * Greenhouse-Geisser correction was used since the data did not meet the assumption of sphericity. Initial = value prior to the intervention; Micro = value taken at the end of the corresponding microcycle. Abbreviations: EXP = experimental group; CONT = control group.

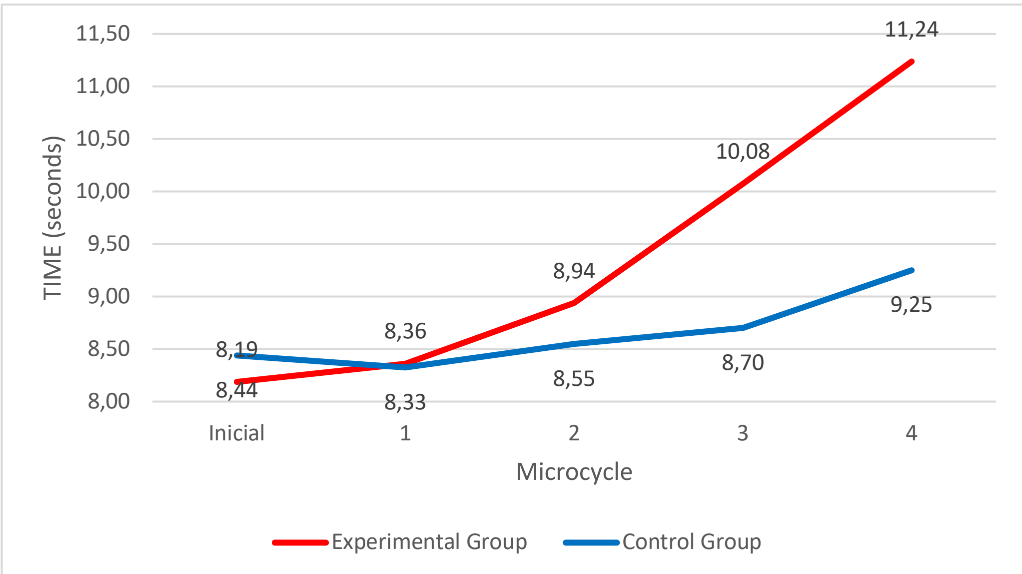

Figure 4. Performance in the *T*-agility test.

The Post hoc test for both groups can be seen in Table 8 (EXP group) and Table 9 (CONT group). In the first case, it is observed that, with the exception of MiC 1, when compared to the initial value, there is a statistically significant reduction in performance in the successive evaluations considered, with respect to the results of the immediately preceding MiC. In the CONT group, on the other hand, there is only a significant reduction in performance in the test performed in MiC 4 compared to the result obtained in MiC 3.

Table 5
Post hoc test on T-agility test performance for the experimental group.

		Average difference (s)	p-value
Initial Value	Micro 1	-0.18 ± 0.3	0.498
	Micro 2	-0.8 ± 0.3	0.020
	Micro 3	-1.9 ± 0.3	< 0.001
	Micro 4	-3.1 ± 0.3	< 0.001
Micro 1	Micro 2	-0.575 ± 0.3	0.064
	Micro 3	-1.7 ± 0.3	< 0.001
	Micro 4	-2.9 ± 0.3	< 0.001
Micro 2	Micro 3	-1.1 ± 0.3	< 0.001
	Micro 4	-2.3c± 0.3	< 0.001
Micro 3	Micro 4	-1.2 ± 0.3	< 0.001

Note: Holm's test was used. In all cases a significance level of α = 0.05 was established. Initial value = value prior to the experimental intervention; Micro = value taken at the end of the corresponding microcycle.

Table 9
Post hoc comparison of T-agility test performance for the control group.

		Average difference (s)	p-value
Initial Value	Micro 1	0.1 ± 0.2	0.989
	Micro 2	-0.1 ± 0.2	0.989
	Micro 3	-0.3 ± 0.2	0.468
	Micro 4	-0.8 ± 0.2	< 0.001
Micro 1	Micro 2	-0.2 ± 0.2	0.592
	Micro 3	-0.4 ± 0.2	0.117
	Micro 4	-0.9 ± 0.2	< 0.001
Micro 2	Micro 3	-0.2 ± 0.2	0.989
	Micro 4	-0.7 ± 0.2	< 0.001
Micro 3	Micro 4	-0.6 ± 0.2	0.008

Note: Holm's test was used. In all cases a significance level of α = 0.05 was established. Initial value = value prior to the experimental intervention; Micro = value taken at the end of the corresponding microcycle.

Figure 5 shows the correlation between TaT performance and the average session training load applied during each MiC. A positive correlation of $r = 0.683$ was verified, statistically significant ($p < 0.001$), which is interpreted following the Goss-Sampson classification (2019) as high ($0.6 < r \leq 0.8$).

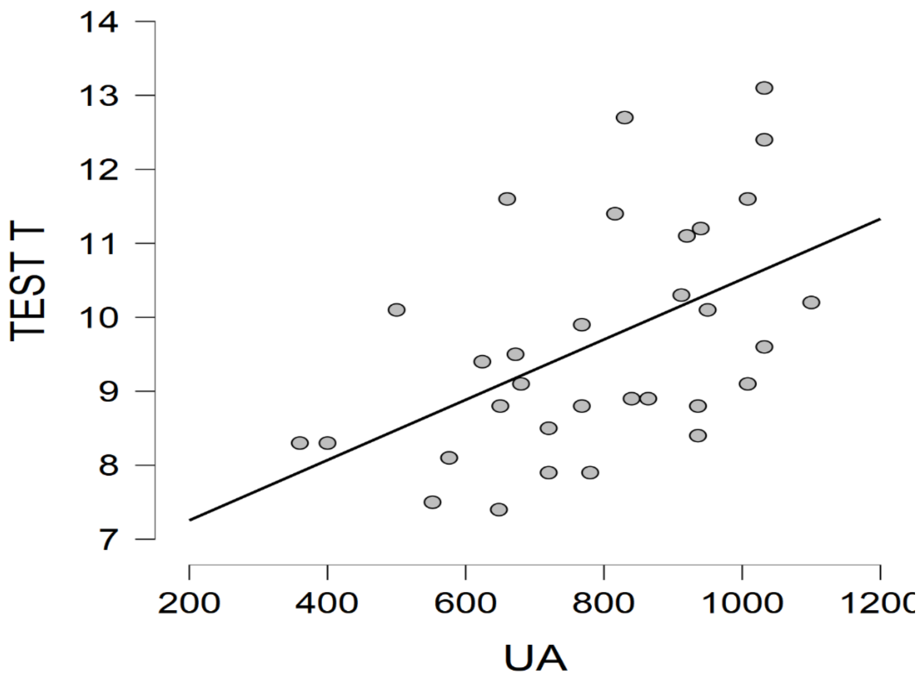

Figure 5. TaT performance as a function of applied load.
Note: Only the results of the experimental group were considered. AU = average session load for the corresponding microcycle, expressed as arbitrary units.

Discussion

The present study investigated the possible usefulness of the CMJ and TaT tests as indirect indicators of accumulated fatigue during a training mesocycle in male youth basketball players. To the best of our knowledge, this is the first study with these characteristics. An important limitation of training intervention works is the lack of a control group (Loturco et al., 2017); for this reason, we consider it relevant to our work to have had such a group.

Prior to the start of the intervention, a significant difference was determined between groups in terms of CMJ performance: the EXP group showed a significantly higher mean performance in this test ($p \leq 0.05$) than the mean observed for CONT (EXP = 39.7 cm vs CONT = 32.8 cm). Considering the purpose of this work; however, we understand that this difference does not affect the conclusions derived from it.

After the intervention, the results obtained in EXP showed a significant decrease in performance for both the CMJ and TaT tests, as the MiCs of training elapsed. In the case of CONT, no such loss of performance was observed in CMJ; while in TaT, the loss of performance was only significant in the test performed at the end of the fourth MiC. Given that both groups trained under the same conditions, it can be assumed that this behavior in the performance variables has as a causal phenomenon the difference in the loads applied. In this regard, we believe that the significant loss of performance in the EXP group would be associated with a process of accumulated fatigue throughout the training mesocycle.

In the study by Delextrax et al. (2012), significant decreases in CMJ performance were observed from 12.6% to 19.6% pre- vs. immediate post-session, during a competitive week. In comparison, in our work the results indicated a percentage loss in

CMJ performance of 16.1%, comparing performance at the end of MiC 4 with pre-intervention values. Given that the loss of performance in both works was similar, it leads us to suggest that the CMJ could present a similar sensitivity to detect both acute (post-session) and chronic (post-mesocycle) fatigue processes.

Other works have analyzed the relationship between training load applied over several training MiCs and CMJ performance, although with inconclusive results. In the work of de Freitas et al. (2018), it was observed that when high training loads were accumulated, CMJ performance showed a decrease, compared to what was observed in periods of application of less stressful loads. These results are in agreement with what was found in the present work. On the other hand, and in the opposite direction, in the work of Freitas et al. (2014), after a precompetitive period in which progressive increases in loads were applied to volleyball players, it was concluded that CMJ performance is not a sensitive variable for the determination of cumulative fatigue. With respect to the TaT, although to our knowledge it has not been used as an indirect indicator of fatigue, it has been observed that other agility tests with similar characteristics (e.g., *arrowhead agility test*) are sensitive to post-competition fatigue (Rago et al., 2020); although we do not know their sensitivity for detecting cumulative fatigue. More studies in this area are needed.

Performance loss in CMJ has been accounted for with accumulation of metabolic products in plasma, including CK (Hagstrom et al., 2018), lactate, and ammonium (Jiménez-Reyes et al., 2011). However, given that in this study each test was performed after an extended period of rest, presumably these products are not affecting performance; as their values would be expected to have dropped to normal by the time the test was run. This suggests that the physiological phenomenon expressed by Jiménez-Reyes et al. (2011) would not be adequate to explain at the physiological level what happened in this study.

In this work, the low loads applied to the CONT group (which averaged 557 AU per session, throughout the entire training mesocycle) were intended to avoid the accumulation of fatigue. Consequently, the significant loss of performance experienced by this group for TaT in MiC 4 compared to MiC 3 raises a question. It could be hypothesized that this is related to a process of loss of athletic form, secondary to the low loads applied after four weeks of low intensity training.

However, we understand that this would not be a convincing justification for this observed phenomenon, given that due to the restrictions imposed by the pandemic caused by COVID-19, the players started the intervention after a prolonged period of inactivity. We can speculate; therefore, that their level of athletic fitness was far from optimal, so that even low training loads should represent a positive adaptation.

We believe it is more pertinent to think that this phenomenon could be due, despite the low loads, to an eventual process of accumulated fatigue at the end of the mesocycle, perhaps caused by a possible incorrect planning in the periodization or rests in the applied program. In any case, given the small number of participants in each group (n = 8), caution is required when drawing conclusions.

The detection of fatigue processes in sport in general, and in basketball in particular, is crucial since fatigue is not only associated with a loss of performance (physical and mental) of players but also with an increase in the occurrence of injuries (Walters et al., 2017). The early detection of potentially deleterious fatigue accumulation processes constitutes a practical tool of undoubted usefulness for coaches, allowing them to adjust and optimize training planning. In this sense, we understand that the findings of the present work represent a contribution, particularly for youth basketball coaches.

Conclusions

The results observed in the present study seem to indicate that both the CMJ and TaT tests are sensitive, and concomitantly useful, for the detection of accumulated fatigue in youth federated basketball players. These findings are encouraging since both tests have a number of advantages, among them: they are inexpensive (in terms of cost and human resources) and do not require a significant logistical organization to carry them out. However, we consider it desirable to combine them with other objective indicators, for example: HR variability, post-exertion HR recovery, movement indicators, among others.

Given the limitations of the present work, we consider that these conclusions should be interpreted with caution. In addition, we believe that more studies similar to the present one are needed.

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