Original Article

Differences in aerobic capacity of basketball players by gender, age, and relative age effect

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ABSTRACT

When playing basketball, athletes must optimally perform repeated short sprints with minimal recovery time, requiring both anaerobic and aerobic abilities, including high VO_{2max}. Yet differences have been seen between young male and female basketball players in this measure. The aim of this quantitative study was to examine differences in players' VO_{2max} by gender, age group, and relative age effect (RAE) using the novel Yo-Yo Recovery Test for Basketball Players. The study included 438 young basketball players, male and female, from a range of Israeli leagues, who were divided into three categories: under-14, under-16, and under-18. To assess RAE, the participants in each category were divided into three trimesters of four months, based on their date of birth. The participants' VO_{2max} was assessed using the novel aerobic test. In this study, we hypothesized that male players will exhibit greater aerobic capacity than female players of the same age and that older players will exhibit greater aerobic capacity than younger ones. Our findings supported these hypotheses, as male players presented better physical fitness results than female players in all age categories. Moreover, female players in the under-18 category presented better results than those in the under-14 category, but not more than those in the under-16. Differences in the relative age effect on performance were seen between the genders and within the female participants. While the male participants presented a steady improvement with age, the results of the girls showed a different pattern. The findings are presented in an achievement table that presents the expected physical fitness results by age and gender, for the benefit of basketball coaches and fitness trainers when assessing their players' aerobic capacity.
Keywords: Performance analysis of sport, Fitness field test, Maximal aerobic capacity, Gender, Yo-Yo Recovery Test, Basketball players.

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INTRODUCTION

As basketball is one of the most popular sports in the world, players make great efforts to reach elite performance levels, practicing on a daily basis and frequently participating in basketball competitions at the national and/or international level (Lidor et al., 2007). To achieve and maintain optimal performance levels, basketball players train in line with predefined short-term and long-term programs, with an emphasis on their need to continuously perform anaerobic activities, such as short sprints and direction changes, with relatively short recovery times (10, 30, or 60 seconds). Yet recovery from such actions is dependent on the players' aerobic abilities, specifically their VO_{2max} (Gottlieb et al., 2022). Moreover, an even greater need for aerobic capacity in basketball players has been seen since 2000, when the shot clock rule was introduced (i.e., the 24 seconds permitted for shooting the ball, instead of the former 30 seconds), as well as the transition to four quarters instead of two halves (Stojanovic, 2018).

For example, the intensity of the game can reach up to 95% of the maximum heart rate (HR) value, with players covering more than 3% of the total running distance over 18 km/h. Players also perform quick transitions between offensive and defensive plays, with about 576 transitions being recorded during a full game. This indicates that players should train at a level that is at least equivalent to the physiological demands of an actual a game. However, the typical movement patterns seen in basketball, such as jumping, defensive steps, and repeated sprinting efforts, are known to cause exercise-induced muscle damage due to a combination of eccentric muscle actions and high-intensity concentricity (Doma, K et al., 2018).

In a study conducted by Scalan (2015), female basketball players were found to perform at greater running work rates than male players, while male players performed more dribbling than female players. Female players also performed more low-intensity shuffling and jumping, as well as longer jogging durations than male players. Yet no gender differences were seen in the players' overall intermittent demands, distance travelled, high-intensity shuffling activity, and sprinting requirements while playing.

Studies indicate that high aerobic fitness could improve recovery time and efficacy in basketball players, as well as muscle strength and power, especially in anaerobic activities such as blocking, rebounding, jumping, and changing directions (Meckel et al., 2009). In light of the importance of aerobic capacity in basketball players, a range of practical assessment tools have been developed over the years (Mancha et al., 2019), that can be used, for example, for defining the baseline for future training and assessments (Stone, 2007). These tests can also offer a clearer indication of which skills and capabilities should be enhanced or maintained in individual basket players, for improving their game performance and outcomes (Mancha-Triguero et al., 2019).

Many physiological aspects of basketball playing mature during childhood, including a person's VO_{2max} values; yet studies show that improved aerobic power can also increase these values at a later age. Moreover, VO_{2max} values in males, in relation to body weight, remain stable over time, unlike the gradual decrease that is seen in females. When measuring aerobic metabolism, VO_{2max} values can be examined via a range of variables, such as the transfer of oxygen by the lungs, heart, and blood vessels. When exercising, the oxygen supply chain responds to the aerobic needs of the muscles that are in action at that time, and may reach maximum capacity, depending on the demand. In adults, VO_{2max} values can therefore serve as an indicator of their cardio-vascular limits or endurance (Rodriguez et al., 2003).

In children and adolescents, however, interpreting VO_{2max} is more difficult, as growth changes may interfere in such measurements. Moreover, maximum oxygen consumption levels gradually increase as the child ages, in light of both muscular and sexual maturation. Studies show that prior to sexual maturity (~12 years of age), VO_{2max} levels may increase by up to 225 ml/min each year, and is 16% greater in boys than in boys. In girls, this increase comes to a halt at about the age of 12 and then begins to decline, whereas in boys, it continues to increase (Ziv, 2009). It is therefore vital that appropriate tests are developed and applied for assessing VO_{2max} in basketball players, depending on their age and gender.

Differences in aerobic capacity by gender and age

Studies show that boys tend to have greater aerobic capacity than girls of similar ages, due to a range of factors, including differences in body composition, size, and hormones. For example, at the age of 14, boys have about 25% more VO_{2max} than girls, due to increased muscle mass in the former compared to increased fat tissue in the latter, as well as higher testosterone levels – thereby creating greater aerobic capacity in boys (Ziv, 2009).

Studies on basketball players tend to focus on developing analytical measuring tools, with the aim of enabling coaches and trainers to optimize their players' performance (Gottlieb et al., 2021). Yet assessment techniques much be sensitive to differences in basketball-playing abilities between players of different genders and ages. For example, dribbling in seen more in male basketball games, while running is seen more in female basketball games (Ziv, 2009). Studies also show that VO_{2max} values among female players are within the 44.0-54.0 mLO_2/kg/min range, compared to the 50-60 mLO_2/kg/min range among male players (Lidor, 2007). However, large variations can be seen in studies on VO_{2max} values among men, such as 45.3-5.9 mLO_2/kg/min (Gocentas, 2004), 45.3-65.2 mLO2/kg/min (Tavino, 1995), or 49.8-63.4 mLO2/kg/min (Abdelkrim, 2010). Such variations could stem from differences in the measurement tool or protocol that were applied in the various studies.

Effect of age on aerobic capacity

People's VO_{2max} refers to their maximal oxygen uptake – the highest rate at which they are able to consume oxygen during exercise. The VO_{2max} measure is an optimal tool for assessing athletes' aerobic fitness, i.e., the body's ability to deliver oxygen to the muscles while exercising and then use it to generate energy. The degree of this ability differs between people, and depends on components that are involved in the delivery of the oxygen to the muscles (including pulmonary, haematological, and cardiovascular elements), as well as on the oxidative mechanisms of the muscles that are taking part in the current exercises (Armstrong, 2006).

In young males, a gradual increase is seen in their VO_{2max}, from age 8 to 16 years, with the greatest annual increases occurring between the age of 13-15 years. In young females, on the other hand, this increase is less consistent, with their VO_{2max} being on a steady incline until they reach the age of 13 years, at which time it starts to level off. In addition, both the peak VO_{2max} and its gradual increase among young males are higher than among young females (Armstrong, 2006).

Relative age effect on aerobic capacity

In sports, in addition to the athletes' chronological age, the term Relative Age Effect (RAE) is also applied, referring to differences within the same age group. While chronological age differences imply different levels of performance and experience due to physical developmental and maturational, RAE refers to differences between people in the same age category, whereby those who were born earlier in the year present improved physical, emotional, and cognitive development compared to their peers who were born later in the year (Ibañez, 2018). Yet considerable inconsistencies on RAE can been seen in the literature. For example, athletes who were born early in the competition year were more highly represented than those who were born late in that year (Baker, 2007), yet no age-related differences were seen in the relative VO_{2max} of 7–13-

year-old children (McMurray, 2002). As such, a consistent and applicable measuring tool should be used across studies, to enable comparisons and generalizations.

Following this literature review, the aim of the current study was to examine the aerobic capacity of young elite basketball players via their $VO2_{max}$, based on age, gender, and RAE using the validated Yo-Yo Recovery Test for Basketball Players (Gottlieb et al., 2022).

MATERIAL AND METHODS

Participants

The study included 438 young basketball players, both male and female, from five clubs in Israel. First, anthropometric measurements were taken for each participant, including height (m), body mass (kg), and body fat (%). Height was measured using a stadiometer (SECA, Germany) with a 1 cm accuracy; body mass and fat were measured using electronic scales (Tanita BC 418, Japan), with a 0.1-kg accuracy (Slaughter et al., 1988). All participants had been playing basketball for three to eight years, and each week conducted at least two fitness practices, participated in three to five basketball practices, and one league game. The players also had to present a clean bill of health, with no injuries, aches, or ongoing medication.

Procedure

After contacting the basketball clubs and coaches to request their participation in the study, informed consent was received from both the players and their parents. The participants were also informed that their participation in the study was not mandatory. Although anonymity could not be promised due to the nature of the study, the participants and their parents were assured that the utmost confidentiality and scientific rigor would be applied throughout the study, and that the achieved data would only be used for the purpose of this research project. Dates for conducting the study at each club were set, so as not to interfere with their training and competitions.

To eliminate circadian variations, all participants completed the test at the same time of day (6 pm), in normal ambient conditions, and with a temperature of 23.1 ± 0.5°C and relative humidity of 70.5% ± 3.5%. The assessments were conducted by the researchers together with the team's coach, inside official indoor basketballs courts; the participants were required to wear their regular sportswear and basketball shoes. Prior to the study, the players were instructed to refrain from caffeine and other stimulants, alcohol and other depressants, and strenuous physical activities for at least 24 hours prior to the research assessments. They were also asked to not consume food for about three hours prior to the testing. The study was approved by the Bioethics Committee at the first author's affiliated academic institution (registration number 367).

Tools

The novel Yo-Yo Recovery Test for Basketball Players was developed for assessing players' VO_{2max} in relation to their recovery from specific movements that are common in the game of basketball (such as short sprints, changing directions, and defensive strides). During the test, the participants were first asked to run in one direction for 18 meters along a clearly marked path inside the basketball court, followed by 2 meters of defensive strides in the same direction. Without stopping or resting, this was immediately followed by an additional 2 meters of defensive strides in the opposite direction (i.e., towards the starting point), followed by their running back to the starting point for another 18 meters. The participants then had 10-20 seconds recovery, during which time they were required to walk 5 meters in both directions (Appendix 1).

The speed at which the participants were instructed to run for each round was dictated by audio sounds. Moreover, this speed increased from round to round. The participants were asked to perform this procedure until they were too tired to continue, while wearing an HR band on their chest (GARMIN®, Olathe, KS, USA). At this point, the total distance that they had covered was calculated (also via audio recordings), and their physical measures were assessed. (1) Sound file from the novel test; (2) Formula for calculating VO_{2max} = 0.0146x + 32.078, with x representing the distance covered during the test (Gottlieb, 2022); (3) HR; and (4) Table of rate perceived exertion (on a scale of 1-10).

Variables
The following three independent variables were addressed in this study, including (1) *gender* (male/female), (2) *three age groups* (according to their affiliated basketball team): Under-14 (U14), Under-16 (U16), and Under-18 (U18), and (5) *three relative age* groups according to the players' month of birth: *tri1* (January-April), *tri2* (May-August), and *tri3* (September-December). The following four dependent variables were also analysed in this study: (1) *distance* (m), i.e., the number of meters covered during the test; (2) predicted VO_{2max}; (3) HR; and (4) rate of perceived exertion (RPE), on a scale of 1 (easiest) to 10 (hardest).

Statistical analysis
In this quantitative study, means and standard deviations (SD) were calculated for weight, height, and body fat; independent T-tests were conducted for age and gender, and 2-way ANOVA tests were conducted to compare mean differences between the age groups, genders, and relative age groups. Statistical analyses were performed using the SPSS v.21 software (Inc, Chicago, IL, USA); statistical significance was set at $p < .05$.

RESULTS

Table 1 presents the participants' physical characteristics, including weight, height, and body fat by age group and gender.

Table 1. Participants' Physical Characteristics by Mean (SD)

		N	Weight (kg)	Height (m)	FAT%
Male	U18	71	77.3 ± 7.64	1.85 ± 5.28	10.72 ± 1.31
	U16	80	66.3 ± 8	1.79 ± 6.2	10.62 ± 1.27
	U14	70	57.8 ± 8.2	1.72 ± 6.8	11.03 ± 1.29
Female	U18	73	59.8 ± 5.8	1.65 ± 5.01	25.45 ± 4.56
	U16	73	57.7 ± 5.53	1.62 ± 4.76	24.31 ± 3.39
	U14	71	47.2 ± 4.37	1.57 ± 4.96	22.97 ± 5.67

Table 2 presents the participants' descriptive data by gender (including age, distance covered during the test, VO_{2max}, and RPE), and distance by trimester. As seen in Figure 1, significant differences were seen between the genders in their mean distance covered, regardless of age, whereby the mean distance for males (1,421.6 ± 218.8) was significantly greater than for females (1,116.9 ± 137.2). Moreover, improvement in these results in line with increased age was also evident, whereby older players covered greater distances.

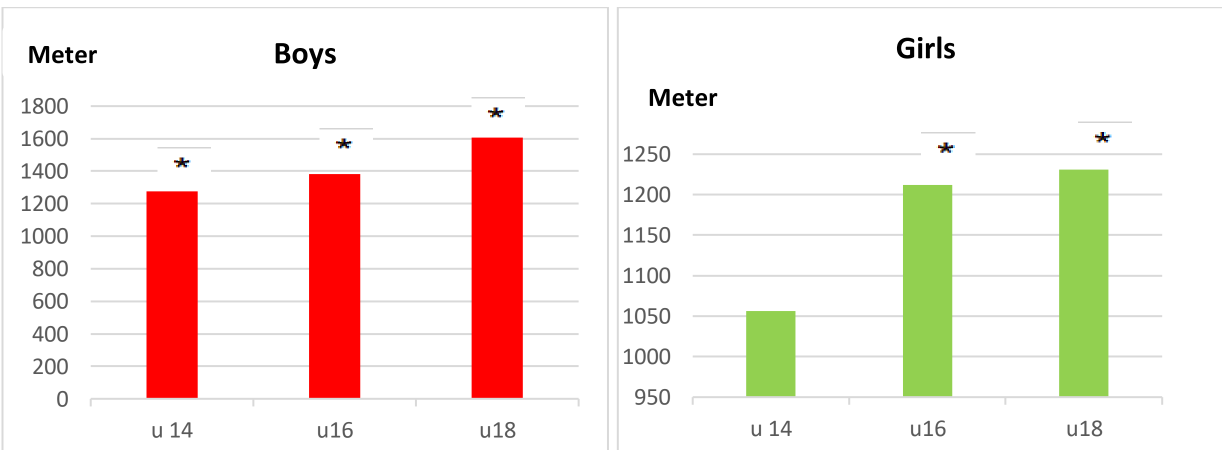
In addition, interactions were also seen between age and gender, whereby improved distances in the female participants began to decrease after the age of 16, unlike the continued increase seen in males at the same ages (Figure 2).

Table 2. Participants' descriptive statistics.

Gender	Age	N	Distance (m)	VO_{2max}	RPE
Males	U14	71	1274.31 ± 195.5	55.5 ± 3.5	7.49 ± 0.48
	U16	80	1383 ± 233.13*	52.27 ± 3.36	7.58 ± 0.49
	U18	70	1607.4 ± 226.03*	50.68 ± 2.8	7.7 ± 0.56
Females	U14	71	1056.34 ± 137.3	47.5 ± 1.99	7.6 ± 0.54
	U16	73	1212.60 ± 129.4*	49.78 ± 1.87	7.61 ± 0.56
	U18	73	1231.78 ± 144.8*	50.06 ± 2.1	7.62 ± 0.48

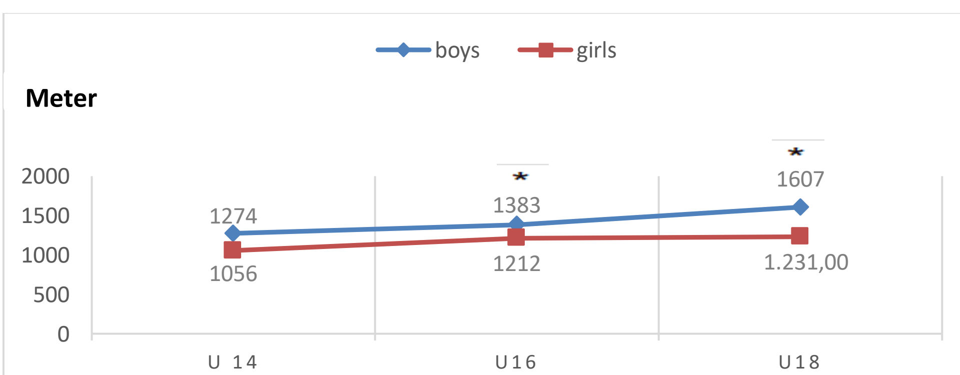
Gender	Distance By Trimester (m)		
	tri 1	tri 2	tri 3
Males	1409.23 ± 178.9	1219.05 ± 89.1*	1176.67 ± 203.2
	1360 ± 250.67	1392 ± 189.78	1360 ± 250.67
	1560 ± 249	1576 ± 213.6	1681.67 ± 210.83*
Females	1204 ± 104.13	1023.45 ± 68*	946.09 ± 44.4*
	1342.4 ± 100.7	1190.67 ± 66.17*	1068.89 ± 40.7
	1385.60 ± 101.9	1209.09 ± 72.9*	1103.08 ± 68.04

Note. * tri1-tri3 * tri2-tri3 *age from previous age group; * gender ($p < .05$).



Note. * Boys U18-U14 and U18-U16 and U16-U14 ($p < .05$). * Girls U18-U14 and U16-U14 ($p < .05$).

Figure 1. Average distances covered by gender.

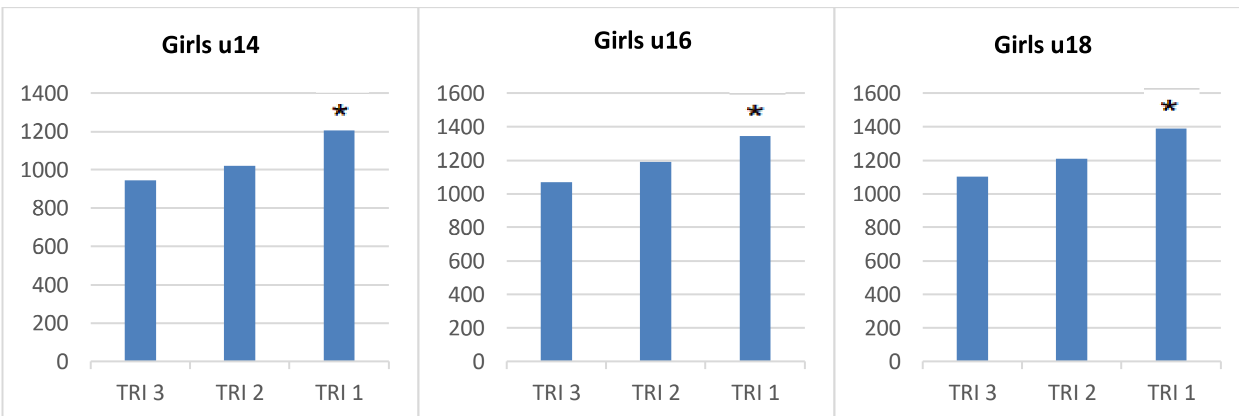


Note. * Between boys-girls in U14 and U16 and U18 ($p < .05$).

Figure 2. Differences in average distances by age and gender interactions.

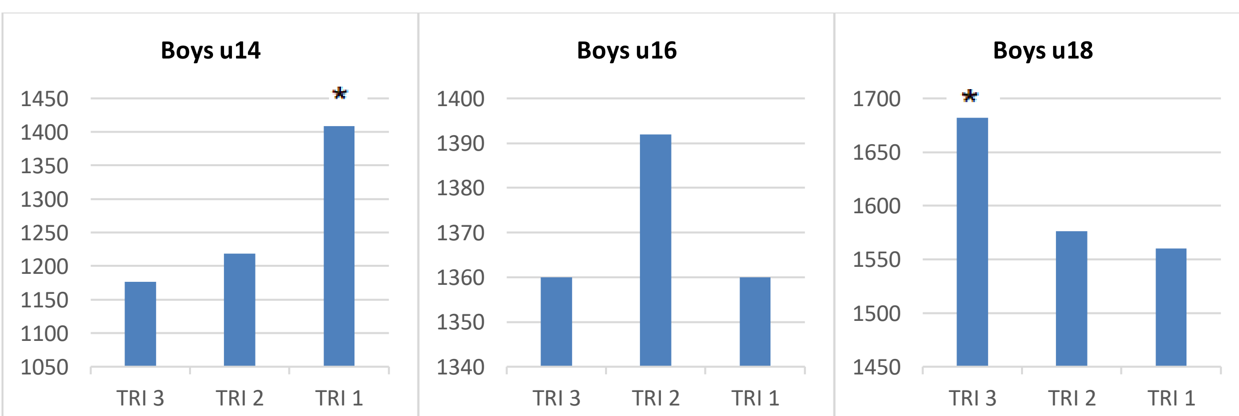
The male participants showed consistent significant improvement in the mean distances covered by age, with a significant increase from U14 (1274.3 ± 195.5) to U16 (1383 ± 233.1), and from U16 to U18 (1607.4 ± 257.8). With the female participants, on the other hand, no such consistency was seen, in light of an increase from U14 (1056.3 ± 1212.6) to U16 (1212.6 ± 129.4), yet with no significant change from U16 to U18 (1231.7 ± 144.8), as depicted in Figure 2. Moreover, when examining interactions between gender and time, different results were seen for each trimester.

When examining RAE among all age groups of *female* participants, a significant decline was seen in performance between trimesters, with the highest score awarded on the first trimester (1329.8 ± 116.5), a steep decline on the second trimester (1135.8 ± 108.5), and the lowest was seen for the third trimester (1040 ± 87.8), as seen in Figure 3. For the male participants, however, interactions were seen across all three trimesters, in addition to an interaction between time and gender. As seen in Figure 4, while the results of the U14 *male* participants followed this pattern of decline throughout the year (tri1 = 1409.3 ± 41.6; tri2 = 1219 ± 46.3; and tri3 = 1176.6 ± 43.3), this pattern is not seen in the U16 or U18 age group.



*Note. *p < .05 tri1-tri2 and tri1-tri3 (U14). * p < .05 tri1-tri2 (U16). * p < .05 tri1-tri2 (U18).*

Figure 3. Female participants: RAE and mean distances.



*Note. * p < .05 tri1-tri2 (U14). * p < .05 tri3-to tri2 and tri1 (U18).*

Figure 4. Male participants: RAE and mean distances.

The declined performance between trimesters in the male U16 group was smaller than that of the female U16 group and of the male U14 group. For all groups, most declines between trimesters were seen between tri1 and tri2, except for the female U14 group, that also exhibited a significant decline between tri2 and tri3. However, in the male U16-year group, no decline was seen between tri1 and tri2, and the decline that was seen between tri2 and tri3 was very small. Interestingly, for the male U18 group, a significant increase was seen between all three trimesters.

The participants' subjectively exerted effort was significantly higher than the measures presented in the literature regarding RPE (Borg, 1998), thereby indicating that they found the test harder than would have been expected of them. No significant differences were found in RPE between the age groups and genders.

DISCUSSION

VO_{2max} plays an important role in the overall athletic performance of young basketball players. This factor relates to the body's ability to utilize oxygen as a means for generating energy when exerting physical activity, and is determined by a number of measures, including genetics, diet, overall health, and training (Lidor, 2007). Correlations between VO_{2max} and activity levels suggest that aerobic conditioning is beneficial in basketball players (Narazaki et al., 2009). In order to perform at high levels, basketball players must also possess good cardiovascular fitness. Basketball requires players to have explosive power, while performing strenuous actions combined with active and passive recovery that depends on VO_{2max}.

Players with high VO_{2max} are able to run and move more quickly on the court, while recovering more quickly from intense physical exertion. In turn, this could provide them with a competitive advantage over players with lower on VO_{2max}. The aim of this quantitative study was to examine differences in players' VO_{2max} by gender, age group, and RAE, using the novel Yo-Yo Recovery Test for Basketball Players. Significant differences were found between genders, as the male participants covered greater distances than the female ones in all age groups. Significant differences were also found in the average distance covered during the test, with better test results seen in older players. Moreover, it was also found that the results of the test varied by RAE, with repeated measures for each trimester yielding different results.

Differences in the effect of age on performance were seen between the genders and within the female participants. While the male participants presented a steady improvement with age, the results of the female participants exhibited a different pattern: Although the female players showed similar improvement from U14 to U16, as did the male players, no significant improvement was seen between U16 and U18. This finding is in line with Ramos et al. (2019), indicating the different effects of puberty on the two genders, and the implications of these differences on athletic performance in general, and on aerobic performance in particular.

When conducting repeated measures across the trimesters, an interaction was seen between age and gender. For the female participants, a similar decline in performance was seen in all age groups across trimesters. This finding is in line with the literature, whereby better results will be seen in players who were born earlier in the year than those who were born later in the year (Susana M. 2021). However, very different results were seen in the group of male players, whereby a similar decline was seen between trimesters in the U14 group, a minor decline was seen between trimesters in the U16 group, and an improvement was seen between trimesters in the U18. Finally, the participants' self-reported RPE scores at the end of the test is in line with similar assessments that relate to VO_{2max} tests, thereby indicating the relevance and reliability of the Yo-Yo Recovery Test for Basketball Players.

Estimated achievement table

Based on the data that was gathered an analysed in this study, we have created an Estimated Achievement Table (Table 3) for the benefit of coaches and trainers of young basketball players. This tailormade scale differentiates between the age and gender of the players and presents the expected distance performance using the using the novel Yo-Yo Recovery Test for Basketball Players, to enable the ranking of players from unprepared to excellent.

Table 3. Achievements Table (Yo-Yo Recovery Test for Basketball Players)

Male			**Female**		
Age	**Distance (M)**	**Assessment**	**Age**	**Distance (M)**	**Assessment**
	1800>	excellent		1370>	excellent
	1601-1800	very good		1231-1370	very good
U18	1401-1600	good	**U18**	1091-1230	good
	1201-1400	poor		951-1090	poor
	1200<	unprepared		950<	unprepared
Age	**Distance (M)**	**Assessment**	**Age**	**Distance (M)**	**Assessment**
	1610>	excellent		1330>	excellent
	1381-1610	very good		1201-1330	very good
U16	1151-1380	good	**U16**	1071-1200	good
	920-1150	poor		941-1070	poor
	920<	unprepared		940<	unprepared
Age	**Distance (M)**	**Assessment**	**Age**	**Distance (M)**	**Assessment**
	1460>	excellent		1180>	excellent
	1271-1460	very good		1051-1180	very good
U14	1081-1270	good	**U14**	921-1050	good
	891-1080	poor		791-920	poor
	890<	unprepared		790<	unprepared

Limitations

Despite its theoretical and practical contributions to the field, this study has some limitation that should be addressed. First, the ability to change directions in basketball is a skill that improves with practice; as such, the results of the younger participants are more likely to be affected by inaccurate technique. In addition, recovery time between rounds in the test is predetermined, unlike in real basketball games, where recovery times may frequently differ. Future studies could benefit from random recovery times between runs (such as 5, 10, 15, or 20 seconds), and an additional task could be added, where after every round, the player has to make a basketball-related decision, such as shooting, passing and dribbling.

CONCLUSIONS

This study implemented the novel Yo-Yo Recovery Test for Basketball Players in young players, both male and female, from five different league club, to assess their aerobic capacity (VO_{2max}) that plays a central role in their ability to recover from anaerobic actions with minimal recovery time. This unique assessment tool is of the utmost importance, as it enables accurate testing on the basketball court, rather than in laboratory settings and is specific to the game of basketball. The main findings indicate that young male basketball players aged 14-18 have greater aerobic capacity than female players of the same ages. Moreover, RAE can be seen in young male basketball players of all age groups (U14, U16, and U18), yet not in young female players.

The Yo-Yo Recovery Test for Basketball Players test offers a new field test for evaluating players' recovery capabilities basketball players – conducted on real basketball courts and requiring less time and distance for achieving the required data. The test can also be modified to suite players of different ages and fitness levels. For example, providing younger and/or less fit players with longer periods of active recovery, or requiring advanced players to run longer distances or at higher speeds during the test. Moreover, when addressing the age of pubertal changes in basketball training, differences between young male and female players should be taken into account. Finally, this unique test could be especially beneficial for basketball trainers and coaches in planning training programs, practices, and games – to achieve optimal outcomes by gender and age.

AUTHOR CONTRIBUTIONS

Roni Gottlieb, Asaf Shalom, Dr. Pedro Emilio Alcaraz, and Dr. Julio Calleja-González conceived and designed the investigation tool, analysed and interpreted the data, drafted the manuscript, and approved the final version submitted.

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DISCLOSURE STATEMENT

No potential conflict of interest were reported by the authors.

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REFERENCES

Abdelkrim, N. B., Castagna, C., Jabri, I., Battikh, T., El Fazaa, S., & El Ati, J. (2010). Activity profile and physiological requirements of junior elite basketball players in relation to aerobic-anaerobic fitness. Journal of Strength and Conditioning Research, 24, 2330-2342. https://doi.org/10.1519/JSC.0b013e3181e381c1

Armstrong, N. (2007). Paediatric exercise physiology. Churchill Livingstone.

Baker, J., & Logan, A. J. (2007). Developmental contexts and sporting success: Birth date and birthplace effects in national hockey league draftees 2000-2005. British Journal of Sports Medicine, 41, 515-517. https://doi.org/10.1136/bjsm.2006.033977

Borg, G. (1998). Borg's Perceived Exertion and Pain Scales. Human Kinetics.

Doma, K.; Leicht, A.; Sinclair, W.; Schumann, M.; Damas, F.; Burt, D.; Woods, C. (2018). The impact of exercise-induced muscle damage on physical fitness qualities in elite female basketball players. J. Strength Cond. Res. 2018, 32, 1731-1738. https://doi.org/10.1519/JSC.0000000000002244

Gottlieb, R. Shalom, A., & Calleja-Gonzalez, J. (2021). Physiology of Basketball - Field Tests. Review Article. Journal of Human Kinetics, 77(1), 159-167. https://doi.org/10.2478/hukin-2021-0018

Gottlieb, R., Shalom, A., Alcaraz, P.E., & Calleja-González, J. (2022). Validity and reliability of a unique aerobic field test for estimating VO2max among basketball players. Scientific Journal of Sport and Performance, 1(2), 103-114. https://doi.org/10.55860/TRMF2461

Gocentas, A., Landor, A., & Andziulis, A. (2004). Dependence of intensity of specific basketball exercise from aerobic capacity. Papers on Anthropology, University of Tartu, 13, 9-17.

Ibañez, S. J., Mazo, A., Nascimento, J., García-Rubio, J. (2018). The Relative Age Effect in under-18 basketball: Effects on performance according to playing position. PLoS ONE 13(7), e0200408. https://doi.org/10.1371/journal.pone.0200408

Lidor, R., Blumenstein, B., & Tenenbaum, G. (2007). Psychological aspects of training in European basketball: Conceptualization, periodization, and planning. Sport Psychologist, 21(3), 353-67. https://doi.org/10.1123/tsp.21.3.353

Mancha-Triguero, D., García-Rubio, J., Calleja-González, J., Ibáñez, S. J. (2019). Physical fitness in B players: A systematic review. The Journal of Sports Medicine 59(9), 1513-1525. https://doi.org/10.23736/S0022-4707.19.09180-1

Meckel, Y., Gottlieb, R., & Eliakim, A. (2009). Repeated sprint tests in young basketball players at different game stages. European Journal of Applied Physiology, 107, 273-279. https://doi.org/10.1007/s00421-009-1120-8

Slaughter, M. H., Lohman, T. G., Boileau, R. A., Horswill, C. A., Stillman, R. J., Van loan, M. D., & Bemben, D. A. Skinfold equations for estimation of body fatness in children and youth. Human Biology, 60(5), 709-723.

McMurray, R. G., Harrell, J. S., Bradley, C. B., Deng, S., & Bangdiwala, S. I. (2002). Predicted maximal aerobic power in youth is related to age, gender, and ethnicity. Medicine & Science in Sports & Exercise (MSSE), 34(1), 145-151. https://doi.org/10.1097/00005768-200201000-00022

Narazaki, K.; Berg, K.; Stergiou, N.; Chen, B. Physiological demands of competitive basketball. Scand. J. Med. Sci. Sports 2009, 19, 425-432. https://doi.org/10.1111/j.1600-0838.2008.00789.x

Ramos, S.; Volossovitch, A.; Ferreira, A.P.; Fragoso, I.; Massuça, L. Differences in maturity, morphological and physical attributes between players selected to the primary and secondary teams of a Portuguese Basketball elite academy. J. Sports Sci. 2019, 37, 1681-1689. https://doi.org/10.1080/02640414.2019.1585410

Stone, N. (2007). Physiological response to sport-specific aerobic interval training in high school male basketball players. Auckland University of Technology.

Scalan, A.T.; Dascombe, B.J.; Kidcaff, A.P.; Peucker, J.L.; Dalbo, V.J. Gender-specific activity demands experienced during semiprofessional basketball game play. Int. J. Sports Physiol. Perform. 2015, 10, 618-625. https://doi.org/10.1123/ijspp.2014-0407

Susana M., Iraia B., Larruskain J., Irazusta J. (2021). The relative age effect in young athletes: A countywide analysis of 9-14-year-old participants in all competitive sports. Plos one. https://doi.org/10.1371/journal.pone.0254687

Stojanovic, E., Stojiljkovic, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M., & Milanovic, Z. The activity demands and physiological responses encountered during basketball match-play: A systematic review. Sports Medicine, 48, 111-135. https://doi.org/10.1007/s40279-017-0794-z

Ziv, G., & Lindor, R. (2009). Physical attributes, physiological characteristics, on-court performances and nutritional strategies of female and male basketball players. Sports Medicine, 39, 547-568. https://doi.org/10.2165/00007256-200939070-00003

Appendix 1. Timetable: Yo-Yo Intermittent Recovery Test for basketball players.

Yo-Yo intermittent recovery test for B (YYRECB)						
Speed level	Shuttle number	Speed (km/hr)	Level time (sec)	Shuttle distance (m)	Time (min)	Estimate VO_{2max} (ml/min/kg)
1	1	6	24	40	00:24	32.66
2	1	8	18	80	00:52	33.25
2	2	8	18	120	01:20	33.83
3	1	9	16	160	01:46	34.41
3	2	9	16	200	02:12	35.00
3	3	9	16	240	02:38	35.58
4	1	10	14	280	03:02	36.17
4	2	10	14	320	03:26	36.75
4	3	10	14	360	03:55	37.33
4	4	10	14	400	04:19	37.92
5	1	11	13	440	04:42	38.50
5	2	11	13	480	06:05	39.09
5	3	11	13	520	06:33	39.67
5	4	11	13	560	06:56	40.25
6	1	12	12	600	07:29	40.84
6	2	12	12	640	07:51	41.42
6	3	12	12	680	08:18	42.01
6	4	12	12	720	08:40	42.59
7	1	13	11	760	09:01	43.17
7	2	13	11	800	09:22	43.76
7	3	13	11	840	09:43	44.34
7	4	13	11	880	10:14	44.93
7	5	13	11	920	10:35	45.51
8	1	14	10.5	960	10:56	46.09
8	2	14	10.5	1000	11:17	46.68
8	3	14	10.5	1040	11:38	47.26
8	4	14	10.5	1080	12:09	47.85
8	5	14	10.5	1120	12:30	48.43
9	1	15	10	1160	12:50	49.01
9	2	15	10	1200	13:10	49.60
9	3	15	10	1240	13:30	50.18
9	4	15	10	1280	14:00	50.77
9	5	15	10	1320	14:20	51.35
10	1	16	9.5	1360	14:39	51.93
10	2	16	9.5	1400	14:58	52.52
10	3	16	9.5	1440	15:17	53.10
10	4	16	9.5	1480	15:46	53.69
10	5	16	9.5	1520	16:05	54.27
10	6	16	9.5	1560	16:23	54.85
11	1	16.5	9	1600	16:42	55.44
11	2	16.5	9	1640	17:01	56.02
11	3	16.5	9	1680	17:20	56.61
11	4	16.5	9	1720	17:49	57.19
11	5	16.5	9	1760	18:08	57.77
11	6	16.5	9	1800	18:27	58.36
12	1	17	8.5	1840	18:45	58.94
12	2	17	8.5	1880	18:57	59.53
12	3	17	8.5	1920	19:15	60.11
12	4	17	8.5	1960	19:43	60.69
12	5	17	8.5	2000	20:01	61.28
12	6	17	8.5	2040	20:19	61.86