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Internal and External Loads in U16 Women's Basketball Players Participating in U18 Training Sessions: A Case Study

Álvaro Bustamante-Sánchez [1,2,3,4,*], Enrique Alonso-Perez-Chao [2,5], Rubén Portes [6] and Nuno Leite [3,4]

1 Department of Sports Sciences, Faculty of Medicine, Health and Sports, Universidad Europea de Madrid, Calle Tajo, s/n, Villaviciosa de Odón, 28670 Madrid, Spain
2 Department of Real Madrid Graduate School, Faculty of Medicine, Health and Sports, Universidad Europea de Madrid, Calle Tajo, s/n, Villaviciosa de Odón, 28670 Madrid, Spain; enrique.alonso@universidadeuropea.es
3 Department of Sports, Exercise and Health Sciences, University of Trás-os-Montes and Alto Douro, 5000-801 Vila Real, Portugal; nleite@utad.pt
4 Research Center in Sport, Health and Human Development (CIDESD), 5000-558 Vila Real, Portugal
5 Department of Physical Activity and Sports Science, University Alfonso X el Sabio, 28691 Villanueva de la Cañada, Spain
6 Performance Department Valencia Basket Club, 46013 Valencia, Spain; rportes@valenciabasket.com
* Correspondence: alvaro.bustamante@universidadeuropea.es; Tel.: +34-902-23-23-50

Abstract

Background: This study aimed to analyze and compare the internal and external training load responses in U16 female basketball players participating in a micro-cycle with the U18 team from the same club. Methods: Twelve U16 and six U18 female basketball players completed two U18-team training sessions (MD-3 and MD-1; 90 min each). The internal load (heart rate metrics) and external load (accelerations, decelerations, speed, and distance) were measured using Polar Team Pro sensors. Differences between groups were analyzed using *t*-tests and Cohen's d effect sizes. Results: No significant differences ($p > 0.05$) were found between age categories for either the internal or external load variables. U16 players showed slightly higher maximum heart rate percentages (96.5% vs. 94.7%, ES = 0.29) but similar average heart rate and time in heart rate zones. For the external load, both groups exhibited comparable values in total distance, average speed, and movement across speed and acceleration/deceleration zones. Effect sizes were mostly small, with moderate differences found in specific acceleration and deceleration zones. Conclusions: U16 players training with the U18 team experienced similar internal and external loads, suggesting that they can cope with the physical and physiological demands of older-age-group training. These findings support the inclusion of younger players in higher-age-group training environments as part of their long-term athletic development.

Keywords: game demands; load monitoring; electronic performance tracking systems; accelerometer; young development

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1. Introduction

Basketball is one of the most popular team sports among females worldwide, ranking second and fourth in participation among women in Australia and New Zealand, respectively, and second among high-school athletes in the United States [1]. Similarly, participation in female basketball has shown steady growth across Europe in recent years, particularly within youth development programs and national competitions [2].

In male youth basketball, players typically cover approximately 84 m per minute per game, with around 93.7% of total playing time spent at low intensities such as standing–walking (<7 km·h^{-1}) or jogging (7–14 km·h^{-1}) [3]. They also perform approximately three accelerations and decelerations per minute per game [4]. From the perspective of external load, these movement demands reflect the intermittent nature of basketball, characterized by frequent changes in speed and intensity [5]. On the other hand, from the perspective of internal load, it has been reported that in female players during official games, the average heart rate is approximately 165 ± 9 beats·min^{-1} (89.1% of maximum heart rate) for the total time and 170 ± 8 beats·min^{-1} (92.5% of maximum) for live time [6]. Understanding these parameters is essential for accurately describing the physical profile of the game and for guiding the development of training strategies tailored to the needs of young athletes [7].

Given these considerations, quantifying the external and internal loads experienced during games across different samples of basketball players becomes essential for designing training and recovery strategies tailored to players' sex, competitive level, and age [8]. Regarding player age, quantifying external game loads among young basketball players is of particular interest given the importance of understanding the ratio of competition-to-training demands in optimizing the overall loading placed on young athletes across their development pathways [9]. In this regard, in youth development programs, it is common for players from the under-16 (U16) categories to take part in training sessions with the under-18 (U18) group, providing an opportunity to assess their adaptation to a theoretically more demanding physical and tactical environment [10]. Within this framework, it is particularly relevant to examine the behavior of these athletes and investigate whether significant differences exist in external and internal load demands according to age category [3,11]. Such analysis may yield valuable insights into more individualized load planning and management aligned with long-term athletic development objectives [12].

To date, most studies have focused on comparing professional and non-professional [13] basketball players in terms of physical demands. However, limited research has examined the differences across youth categories, despite the importance of understanding how developmental stage influences both internal and external loads. García et al. (2021) revealed significant age-related differences in both average physical demands and the most demanding 60 s scenarios across five male basketball age groups (U12 to senior). Interestingly, the U12 players covered the greatest relative total distance on average, surpassing older categories, which may be due to differences in game structure, playing time, and tactical behavior [11]. However, when examining peak demands using rolling averages, older age groups—particularly U18—demonstrated the highest values, especially in high-speed running. High-intensity accelerations and decelerations showed smaller differences between age groups, although U16 players reached the highest peaks in the most demanding scenarios. Overall, the results suggest that while younger players may display higher movement volumes during games, older players are exposed to greater intensities during peak periods, highlighting the importance of tailoring training and recovery strategies according to the specific physical profiles of each developmental stage [11].

While the study compared male basketball players across different age categories, it did not account for situations in which players from one age group train or compete with older teams. This is an important consideration, as observed differences in physical demands might not be solely attributed to age, but rather to the specific training loads and competitive contexts these players are exposed to when playing at a higher level. In this regard, research should explore whether such differences are truly age-related or driven by the increased demands associated with participating in higher-level environments. In turn, there is still little knowledge about the influence of training with a higher age category for women's basketball players, which is important to determining whether the external and internal load demands differ by age and to ensure appropriate workload management during key developmental stages of athletic development. Therefore, the aim of this study was to analyze and compare training load responses for U16 women's basketball players training in a micro-cycle (one-week training sessions on Match Day-3 [MD-3] and Match Day-1 [MD-1]) with the U18 female team from the same club. It is hypothesized that U16 players will exhibit similar or lower external loads, but significantly higher internal loads compared to U18 players when training with the U18 team.

2. Materials and Methods

2.1. Participants

We analyzed 12 U16 (mean $\pm$ standard deviation (SD): height, 164.8 $\pm$ 5.42 cm; weight, 54.7 $\pm$ 5.42; 4 guards, 4 forwards, and 4 centers) and 6 U18 (mean $\pm$ SD: height, 173.2 $\pm$ 8.61 cm; weight, 64.2 $\pm$ 9.93 kg; 2 guards, 2 forwards, and 2 centers) women's basketball players in two U18-team consecutive training sessions of 90 min length for MD-3 and MD-1. These training sessions were part of the systematic implementation of the regular in-season training structure of the team, following a standardized weekly schedule to ensure ecological validity and consistency in training content and load distribution. Both training sessions were planned and supervised by the same head coach, and both age groups maintained the same number of players on each positional role (guard, forward, and center) for each session. Before starting the research, the experimental procedures were explained to all the participants, who gave their voluntary written informed consent in accordance with the Declaration of Helsinki. The procedures conducted in the present research were designed and approved by the Ethical Committee of the University (UID/04045).

2.2. Procedure

We analyzed the training loads through the following parameters of intensity: heart rate, accelerations, decelerations, and speed. The training sessions consisted of 77.0 $\pm$ 1.41 min of playing time and 13.0 $\pm$ 1.41 min of pauses for drill explanations, breaks between drills, water breaks, or organizational pauses. The duration of active and passive periods during the sessions was determined through manual direct observation by a researcher experienced in basketball training analysis, using a digital stopwatch. The start and end times of each task, as well as pauses were systematically recorded. This procedure ensured accurate and consistent temporal segmentation across both training sessions. The training sessions consisted of the following drills. For MD-3: (1) shooting, (2) 3-point line closeout 1-on-1, (3) 11-fast-break, (4) shooting, (5) free-throws, (6) half-court 4-on-4, (7) shooting, (8) free-throws, (9) 5-on-5, and (10) free-throws. For MD-1: (1) shooting, (2) half-court 5-on-5, (3) square passing-game, (4) 1-on-1 with defender behind, (5) 3-point line closeout 1-on-1, (6) half-court 1-on-1 non-dominant hand, (7) shooting competition in groups of 3, (8) 5-on-5, and (9) free-throws. Both the U16 and U18 players participated in the same training sessions as the U18 team, following the club's standardized season structure. All sessions were designed and led by the same coach, ensuring identical content, sequence, and duration of tasks for all participants. This design allowed for direct comparisons of internal and external load responses between younger and older players exposed to the same training stimulus, assessing their ability to adapt to higher-level competitive demands. Both U16 and U18 players participated together under identical conditions—facing the same teammates, opponents, and tactical tasks—which ensured the standardization of contextual and interactive factors throughout the sessions analyzed.

2.3. Instrumentation and Study Variables

All participants wore motion sensors (Polar Electro Oy, Kempele, Finland) with a heart rate monitor, accelerometer, and gyroscope. Players wore the same device throughout the study period to avoid inter-device variation in external load data outputs [14]. Internal and external loads were assessed through the Polar Team Pro sensors and software (Polar Electro Oy, Kempele, Finland), following the procedures of previous studies carried out in basketball [15–18] and the manufacturer's recommendations. The sensor consisted of an integrated device including a heart rate-sensor, accelerometer, gyroscope, and GPS. It was placed on a chest strap just below the sternum. Before each session, the correct calibration and connection of the devices were verified using the Polar Team Pro software, ensuring accurate signal detection and data synchronization. Each player always used the same device throughout the study period to avoid inter-device variability.

We analyzed the following internal load variables through the Polar Team Pro heart rate monitor the Polar Team Pro software v2.0:

- Heart rate: maximum [bpm], average [bpm], time in zone 1 (50–60%) [min], time in zone 2 (60–70%) [min], time in zone 3 (70–80%) [min], time in zone 4 (80–90%) [min], and time in zone 5 (90–100%) [min].

External load variables were analyzed through the Polar Team Pro 200 Hz MEMS motion sensor (accelerometer and gyroscope):

- Accelerations (m/s^2): number of accelerations in zone 1 (0.50 to 0.99 m/s^2), number of accelerations in zone 2 (1.00 to 1.99 m/s^2), number of accelerations in zone 3 (2.00 to 2.99 m/s^2), and number of accelerations in zone 4 (3.00 to 50.00 m/s^2).
- Decelerations (m/s^2): number of decelerations in zone 1 (-0.99 to -0.50 m/s^2), number of decelerations in zone 2 (-1.99 to -1.00 m/s^2), number of decelerations in zone 3 (-2.99 to -2.00 m/s^2), and number of decelerations in zone 4 (-50.00 to -3.00 m/s^2).
- Speed: average speed [km/h], distance in the speed zone 1 [m] (3.00–6.99 km/h), distance in the speed zone 2 [m] (7.00–10.99 km/h), distance in the speed zone 3 [m] (11.00–14.99 km/h), distance in the speed zone 4 [m] (15.00–18.99 km/h), and distance the speed zone 5 [m] (19.00 km/h and above)
- Distance: total distance [m] and distance per minute [m/min].

2.4. Statistical Analysis

Normality assumptions were tested using the Shapiro–Wilk test. Homoscedasticity assumptions were checked with the Levene test. Descriptive statistics were presented as mean and SD. Differences between U16 and U18 groups were analyzed with a *t*-test. The effect size (ES) was tested by Cohen's d, and interpreted as small for <0.5 absolute values, medium for 0.5–0.8 absolute values, and large for absolute values greater than 0.8. The Jamovi 2.5.4 for Windows (Jamovi Project, Sydney, Australia) and SPSS (version 26.0; SPSS, Inc., Chicago, IL, USA) were used to develop the statistical analysis, and Python v3.0 (Python Software Foundation, Wilmington, DE, USA) was used to develop the figures. The level of significance for all the comparisons was set at $p < 0.05$.

3. Results

Figure 1 shows box and violin plots for internal loads in the U16 and U18 categories. Box and violin plots were used as they provide a clear visualization of the distribution, density, and central tendency of the data, which is particularly effective when comparing external and internal load demands between groups. There were no significant differences ($p \geq 0.05$) between categories. We found greater values for U16 in the percentage of maximum heart rate (96.5 ± 6.15 vs. 94.7 ± 7.09, ES = 0.286), but lower values for U16 in the percentage of average heart rate (70.8 ± 5.51 vs. 72.3 ± 6.62, ES = −0.252), both with a small effect size. We found similar values for the U16 and U18 groups in the total number of minutes on each heart rate zone: zone 1 (50–60%) (13.5 ± 4.87 vs. 13.7 ± 10.80, ES = −0.022), zone 2 (60–70%) (16.6 ± 3.09 vs. 15.1 ± 5.22, ES = 0.400), zone 3 (70–80%) (18.5 ± 5.03 vs. 20.2 ± 7.04, ES = −0.292), zone 4 (80–90%) (20.4 ± 7.76 vs. 18.4 ± 9.62, ES = 0.237), and zone 5 (90–100%) (5.42 ± 6.92 vs. 7.40 ± 9.72, ES = −0.254). The effect size for all these variables was small.

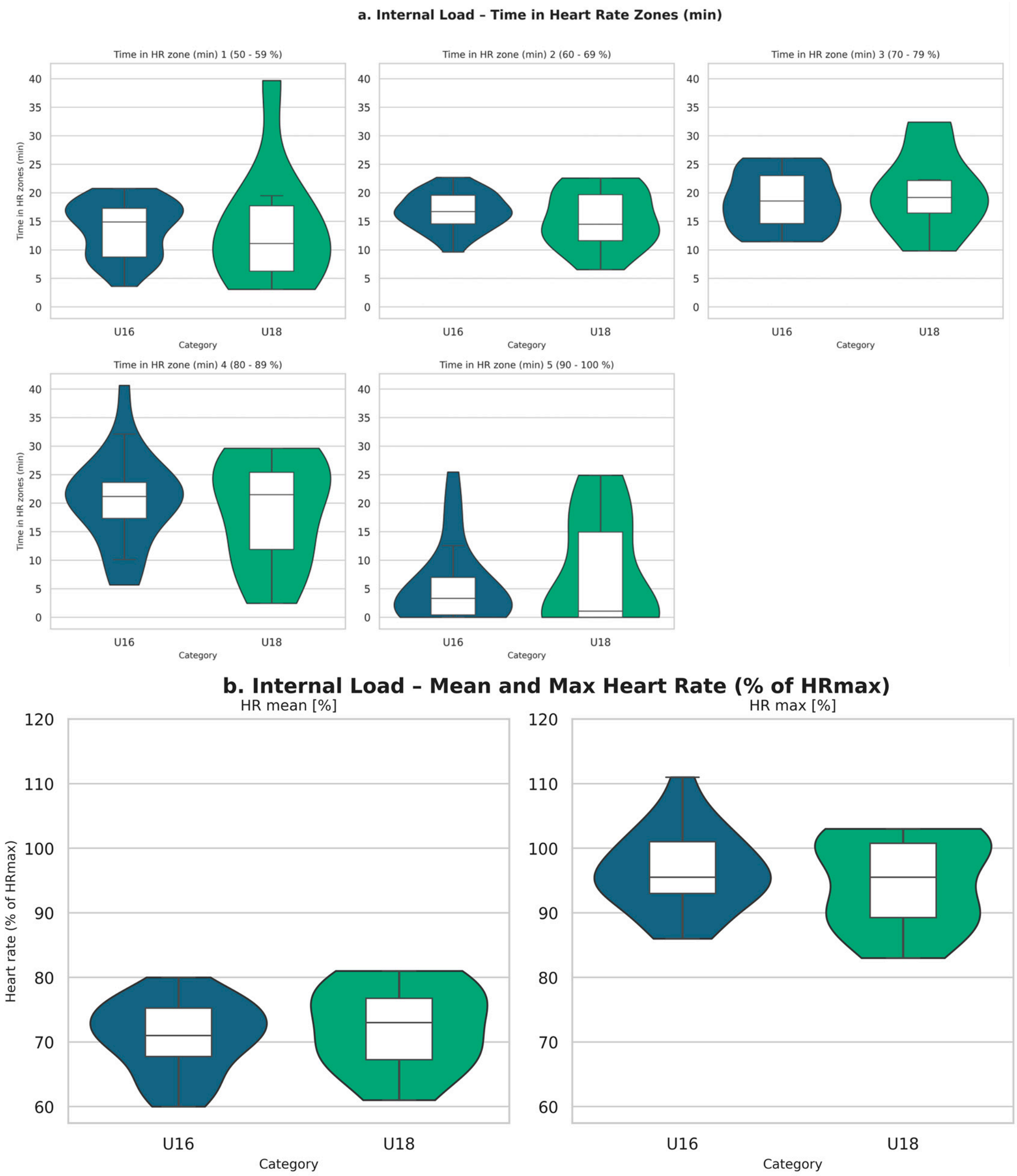

Figure 1. Internal load: heart rate. *Note*: there were no significant differences ($p \geq 0.05$) between categories.

Figure 2 shows box and violin plots for external loads (accelerations and decelerations) in the U16 and U18 categories. There were no significant differences ($p \geq 0.05$) between categories.

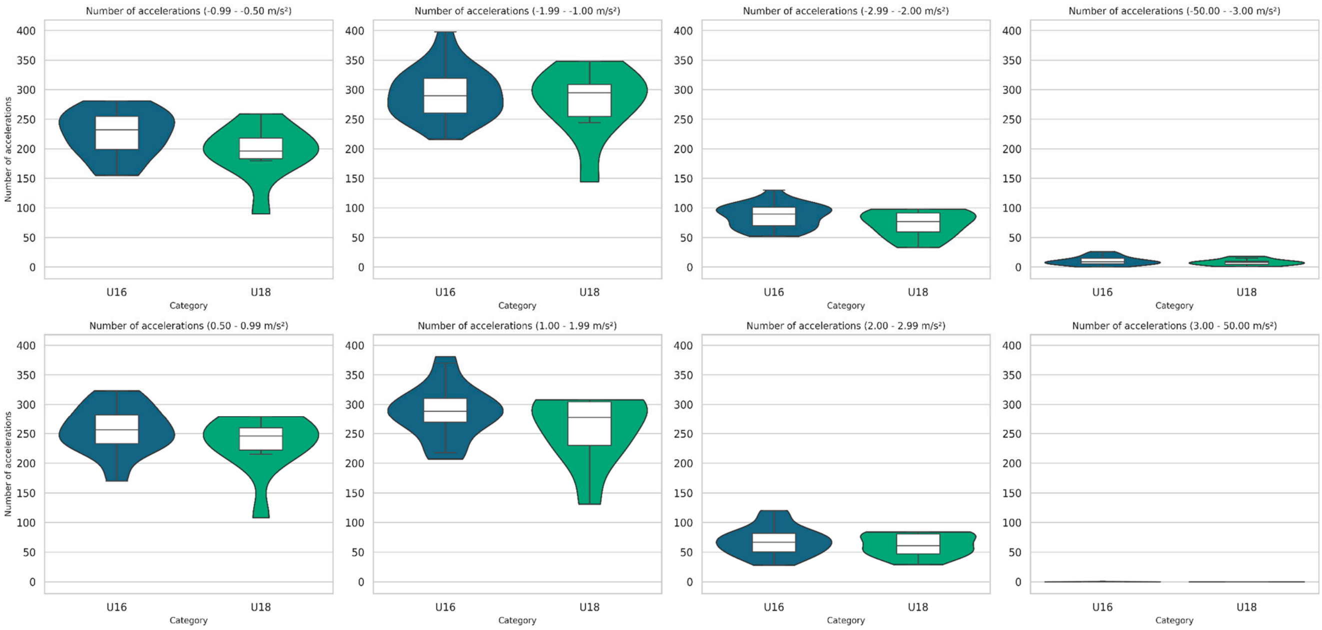

Figure 2. External load: accelerations and decelerations. *Note*: there were no significant differences ($p \geq 0.05$) between categories.

We found similar results for the U16 and U18 groups in the total number of accelerations in zone 1 (0.50 to 0.99 m/s^2) (256.87 ± 39.48 vs. 233.1 ± 48.8, ES = 0.561), accelerations in zone 2 (1.00 to 1.99 m/s^2) (286.00 ± 44.16 vs. 259.2 ± 58.03, ES = 0.553), accelerations in zone 3 (2.00 to 2.99 m/s^2) (68.5 ± 24.31 vs. 62.2 ± 19.26, ES = 0.273), and accelerations in zone 4 (3.00 to 50.00 m/s^2) (0.04 ± 0.20 vs. 0.00 ± 0.00, ES = 0.240). The effect size was moderate for accelerations in zones 1 and 2, and small for accelerations in zones 3 and 4.

Similarly, no differences were found for the number of decelerations in zone 1 (−0.99 to −0.50 m/s^2) (225.0 ± 38.48 vs. 195.4 ± 44.54, ES = 0.734), decelerations in zone 2 (−1.99 to −1.00 m/s^2) (293.08 ± 43.02 vs. 279.6 ± 57.5, ES = 0.283), decelerations in zone 3 (−2.99 to −2.00 m/s^2) (85.80 ± 20.10 vs. 72.60 ± 22.07, ES = 0.639), and decelerations in zone 4 (−50.00 to −3.00 m/s^2) (10.45 ± 7.10 vs. 8.20 ± 5.26, ES = 0.340). The effect size was medium for decelerations in zones 1 and 3, and small for decelerations in zones 2 and 4.

Figure 3 shows box and violin plots for external loads (speed and distances) in the U16 and U18 categories. There were no significant differences ($p \geq 0.05$) between categories.

The results were consistent for the U16 and U18 groups in the total distance [m] (3146.0 ± 559.4 vs. 2907.5 ± 651.1, ES = 0.406), average speed [km/h] (13.5 ± 4.87 vs. 13.7 ± 10.80, ES = 0.190), and distance [m/min] (36.6 ± 6.39 vs. 33.8 ± 7.50, ES = 0.413). The effect size was low for all these variables. However, it is important to note that the total distance and distance [m/min] present values close to the medium effect size threshold.

We did not find differences between age groups for U16 and U18 players in the number of meters run in the speed zone 1 (3.00–6.99 km/h) (1465.62 ± 193.84 vs. 1421.80 ± 334.17, ES = 0.181), in the number of meters run in the speed zone 2 (7.00–10.99 km/h) (709.95 ± 158.12 vs. 605.70 ± 172.63, ES = 0.642), in the number of meters run in the speed zone 3 (11.00–14.99 km/h) (482.16 ± 144.02 vs. 467.5 ± 174.75, ES = 0.095), in the number of meters run in the speed zone 4 (15.00–18.99 km/h) (215.45 ± 125.86 vs. 174.60 ± 75.309, ES = 0.358), and in the number of meters run in speed zone 5 (above 19.00 km/h) (42.75 ± 53.64 vs. 22.20 ± 38.15, ES = 0.412). The effect size was medium for speed zone 2, and small for speed zones 1, 3, 4, and 5.

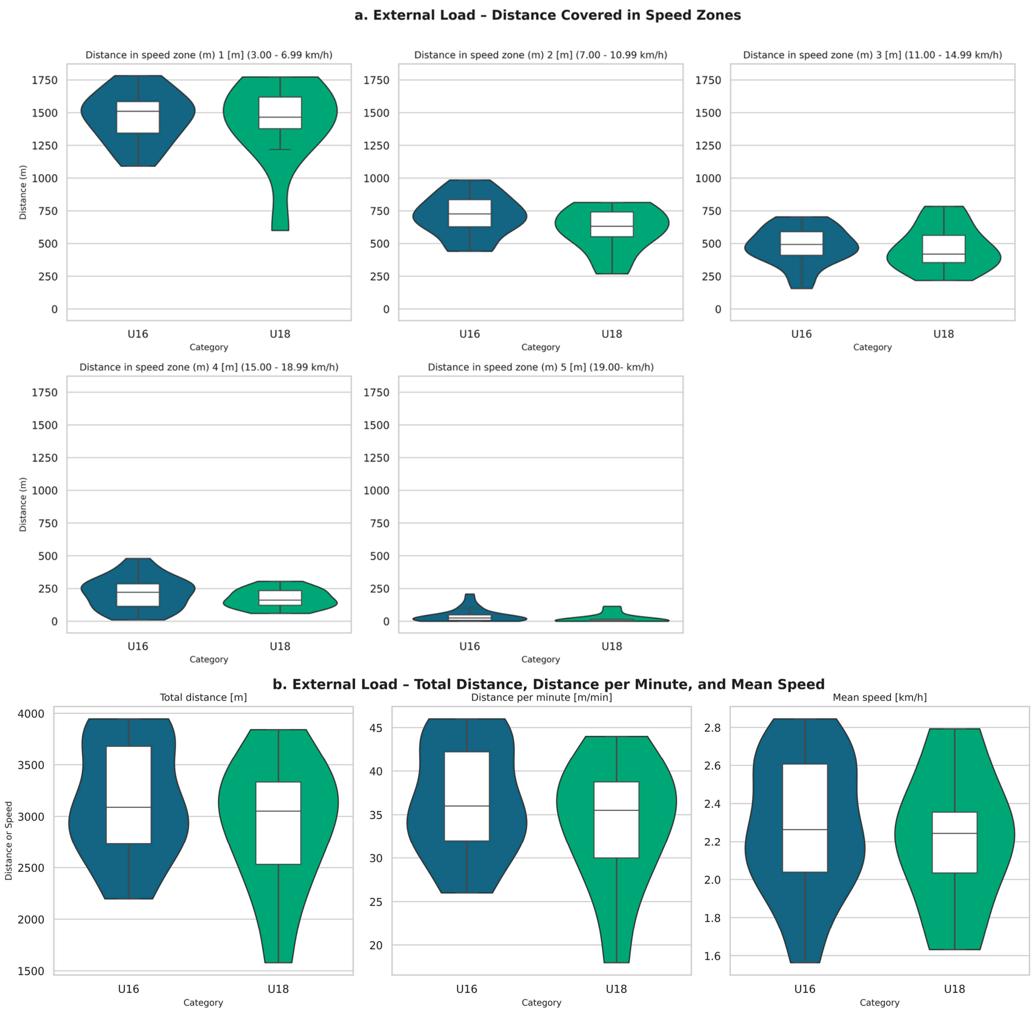

Figure 3. External load: speed and distances. *Note*: there were no significant differences ($p \geq 0.05$) between categories.

4. Discussion

The aim of this study was to analyze and compare the training load responses of U16 female basketball players during a micro-cycle in which they trained with the U18 team. The results showed no significant differences between the two groups in either internal or external load variables. Both U16 and U18 players displayed comparable values in heart rate responses, distance covered, average speed, and acceleration/deceleration counts, with only small-to-moderate effect sizes in specific variables.

The initial hypothesis of the present study was that U16 players would exhibit similar external load values with higher internal load values in response. Maturation process, as well as age-related differences in cardiovascular efficiency, thermoregulation, and autonomic recovery, could be several explanations for this initial thought, as older players during youth sports seem to elicit higher physical capacities than their younger counterparts [19]. Although the results of this study showed higher values of maximum heart rate for the U16 players in response to the same demands as the U18 players, the average values as well as time in different HR zones were similar; therefore, physiological responses and capacities between both age groups seem also very similar for this specific playing level and age groups. More specifically, the number of accelerations and decelerations in all four intensity zones we similar for both groups, as well as the total distance, distance (m/min), and average speed.

Regarding the external load, García et al. (2021) found differences in the high-speed distance running between age groups (U12, U14, U16, and U18) in male youth basketball [11]. Nevertheless, the U16 and U18 groups achieved similar values, results that are similar to the ones obtained in the present study when comparing the same female age groups. Forte et al. (2019) also studied differences in physical fitness (strength levels, coordination, speed, and flexibility) between the same age groups as in this study (U16 and U18) and found significant differences between both age groups, which could explain the similarities in the results obtained in the previous mentioned study [20].

Nevertheless, there are differences between youth male and female basketball players regarding the physical demands experienced during competition [21]. In this regard, Portes et al. (2022) studied differences between male and female junior players during competition, reporting that the main differences exist in the volume and the intensity of the distance covered, with males being the ones with higher values [21]. Acceleration/deceleration ratios were also analyzed, being higher for the female group and showing that strength levels at this age could be a considerable difference between groups [21]. Therefore, any similarities between the sexes at these age groups should be considered carefully before making conclusions, especially due to the difference in context between the mentioned study, developed during competition, and the present one executed in a training environment.

Differences in the demands of the different playing positions also exist in U18 female basketball players. The differences in the acceleration and deceleration profiles of this age group during competition have been studied, and there were found significant differences according to quarter, playing time, and playing position. Centers performed fewer accelerations than guards and forwards during playing, and higher numbers of accelerations and decelerations were performed in the second and last quarters [4]. The present study focused on the overall demands of the different age groups and compared them to obtain a general vision of the capacity of the younger group to cope with the same physical and physiological demands as the older group, but future studies could focus on the needs of different playing positions, as they seem to be different [11,21] and need to be assessed individually to have a better understanding of their specific training processes.

The capacities and performances of youth basketball players also depend on the accumulated training as well as maturity status [22,23]. Therefore, to analyze similarities between both groups we would have to focus also on accumulated training history which could not be homogeneous between both, as well as maturation status, which could also affect results due to disparities of maturation between individuals of different ages regardless of their natural age group. The fact that, usually, when younger players are called to practice with higher age groups, there is also a motivational component involved that could help boost the performance of the individuals incorporated into the older group, could also affect the results observed regarding observed similarities between both groups, as relations between functional performance and psychological disposition have been found in previous literature [22].

These mentioned factors could have contributed to erasing existing physical differences between both groups that were stated before in previous literature [24]. The level of strength between the age and sex groups included in this study seems to be different, as Fort-Vanmeerhaeghe et al. (2016) found significant differences in upper and lower limb strength between U16 and U18 female basketball players, with the U18 group showing considerably higher values; nevertheless, this fact did not influence the match performance of both groups, which was similar when comparing different basketball performance indicators [24]. As mentioned before, motivation and a rise in psychological activation and disposition can play a definitive role in helping the younger players to raise their performance and match the older groups when they practice or play together.

Nevertheless, cautioun should be applied when proposing that U16 players could tolerate the same loads as their U18 counterparts in the long term, as this study was executed in a short time window. In this regard, the loads of the U18 program would probably have to be modified in their intensity and volume to allow progressive adaptation by the U16 group and therefore create the capacity to tolerate them in the long term. Additionally, the results imply responses to the training loads in the session, but caution should also be applied when interpreting equivalence in the performance capacities between both groups.

This study presents several strengths: it provides insightful information about how younger female basketball players respond to training loads of an older category, developing an ecological context in which to assess training demands and load distribution. The content of the sessions should also be taken into consideration as they might not be enough to expose differences in performance between both groups. It also presents limitations: the main limitation is the small sample size, which reflects the actual composition of the team and the applied nature of the study. It constitutes a limitation that may decrease statistical power and increase the risk of type II error, especially for the detection of small or moderate effects. To mitigate this limitation, effect sizes (Cohen's d) were reported and interpreted alongside significant values, providing a more complete interpretation of the practical relevance of the results. In future research with larger sample sizes, the use of bootstrapping confidence intervals could be considered to enhance the robustness of the results.

4.1. Practical Applications

These results suggest that U16 players can manage U18 training sessions from a mechanical and physiological perspective. Moreover, these findings offer some general practical guidelines for coaches aiming to integrate younger athletes into older training groups in a safe and developmentally appropriate manner. Younger players may be integrated into higher-age-group training environments without experiencing excessive physical or physiological stress, provided that appropriate monitoring and load management strategies are in place. To minimize the risk of overuse injuries or maladaptive responses, it is recommended that youth athletes limit their participation to one training session per day [25]. Avoiding double sessions is particularly important during periods of increased exposure to higher intensity or volume, ensuring that cumulative training loads remain within tolerable limits [9].

In this context, it is crucial that coaches account for individual differences in maturational status and previous experience when planning training integration. Chronological age does not necessarily reflect an athlete's readiness to cope with the demands of older-age-group environments. Therefore, progression in training volume and intensity should be tailored based on each player's biological development, technical proficiency, and psychological readiness to ensure both safety and optimal adaptation [9]. Monitoring strategies such as ACWR (acute to chronic workload ratio) and HRV (heart rate variability) could be useful when determining the capacity of the players to cope with the proposed training load.

Cross-category training may be especially beneficial during sensitive developmental periods, when athletes display heightened potential for adaptation. Beyond physical gains, such exposure offers valuable opportunities for growth in cognitive, technical, and emotional domains [26]. Participating in faster-paced games and more tactically complex situations can foster quicker decision-making, improve technical execution under pressure, and enhance self-confidence and intrinsic motivation [3]. These multifaceted benefits highlight the broader developmental value of carefully structured cross-age training experiences.

4.2. Future Studies

Future research should consider players' maturational age, as chronological age alone may not accurately reflect individual physical development and adaptation capacities. In addition, studies involving larger and more diverse samples across different clubs, competitive levels, and regions would help to generalize findings and identify potential variability in training load responses. It is also essential to account for additional contextual variables, including the specific training content, coaching methodologies, athlete motivation, and prior exposure to higher-level competitive environments, as these factors may significantly influence the way young players adapt to increased physical and tactical demands.

5. Conclusions

U16 female basketball players demonstrated similar internal and external training load responses compared to U18 players when participating in the same training micro-cycle. These findings suggest that younger athletes are capable of coping with the physical and physiological demands of older-age-group training environments. This supports their integration into higher-level training as part of long-term athletic development strategies, provided that individual monitoring and workload management are maintained. Ultimately, this highlights that training "up" may not only be feasible, but also a valuable opportunity to stretch developmental boundaries without necessarily increasing physical strain. Nevertheless, and as previously stated, the limitations of the study, particularly the short observation period and the small sample size, should be taken into consideration, and further studies could extend the present one with more longitudinal data and bigger sample sizes to give a wider context to the results obtained in this one.

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