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A comparison of maximal acceleration between the "tic-tac" parkour action, drop jump and lay-up shot in youth basketball players: A preliminary study towards the donor sport concept.

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Abstract

The aim of this cross-sectional study was to compare acceleration outputs of the parkour-style "tic tac" action with those of the drop jump and the lay-up shot in youth basketball players. A total of 25 participants (17 males, 13.80 ± 1.30 years of age; and 8 females, 15.00 ± 0.80 years of age) completed three trials of each action while wearing a single inertial motion capture unit with a sampling frequency of 200 Hz, positioned at the lumbar spine. All data was captured in a single session, using the same test order for all participants. Maximum resultant acceleration was calculated from the raw data for each action. Using sex and maturation status as covariates, data were analysed using a Bayesian one-way repeated measures ANCOVA. Results revealed the jump + sex model to be the best fitting (BF_{10} = 9.22 x 10^5). Post hoc comparisons revealed that the tic tac produced greater maximal acceleration than the drop jump and the lay-up. These findings provide a biomechanical basis for the potential use of the parkour tic tac as an activity that could be used within the athletic development of youth basketball players.

Key Words

Accelerometery; parkour; youth basketball; donor sports; motor skill

Introduction

Within youth athletic development models (e.g., the Long-term Athlete Development model (Balyi et al., 2013) and Youth Physical Development model (Lloyd & Oliver, 2012)), an emphasis is often placed on the fundamental movement skills and the enhancement of physical capabilities (e.g., strength, speed, agility) required for participation in organised sports (Balyi et al., 2013; Liefeith et al., 2018; Lloyd & Oliver, 2012). Classically, fundamental movement skills represent skills related to locomotion (e.g., running, skipping, galloping), object manipulation (e.g., striking, catching, kicking), and balance (Barnett et al., 2016; Smith, 2016). The development of fundamental movement skills is typically recommended in pre-adolescents who, ahead of peak height velocity, are understood to acquire motor skills more readily than older youth due to higher levels of brain and nervous system plasticity (Behringer et al., 2011; Myer et al., 2015; Williams, Ramirez-Campillo, et al., 2021). Accordingly, the years preceding adulthood have been referred to as a golden period of motor learning (Myer et al., 2015; Solum et al., 2020). Moreover, training to enhance different physical capabilities has been recommended to coincide with stages of maturation to augment the natural changes occurring in the growing bodies of young athletes (Lloyd et al., 2011, 2015; Moran et al., 2018). However, in sports such as basketball, the adoption and implementation of these broader youth athletic development strategies may be overlooked by coaches in favour of sports-specific practice (Owoeye et al., 2020; Williams, Hammond, et al., 2021).

In contrast to the Long-term Athlete Development and Youth Development models, the more recently conceived Athletic Skills model (Wormhoudt et al., 2018) presents a pedagogical approach to athletic development that is based upon concepts from the ecological dynamics framework. Ecological dynamics is an integrated theoretical framework that combines ecological psychology with dynamical systems theory in the study of human behaviour (O'Sullivan et al., 2020). Accordingly, the ecological dynamics framework views motor skill performance as the resultant outcome of the fluid interaction between the individual performer, the specific motor task, and the environment within which the task is performed (Davids et al., 2013; Woods et al., 2020).

One of the tenets of the Athletic skills model is the notion of so-called "donor sports" (Wormhoudt et al., 2018). Donor sports are theorised to *donate* action capabilities to a *target sport* through the utilisation of transferable physical skills and perception-action capabilities (Rudd et al., 2015; Strafford et al., 2018). Through the ecological dynamics lens, the performer perceives their surrounding environment in terms of their ability to act within it, accounting for both the different environmental properties (e.g., surface, dimensions, objects) as well as the performer's current action capabilities (e.g., skills, physical capabilities) (Witt & Riley, 2014). Accordingly, the donor sport concept offers an attractive strategy to develop broad both fundamental movement skills and physical characteristics in a way that the performer can utilise within their chosen sport.

Based upon the donor sports concept, the use of parkour-style training activities has been proposed as a method of developing movement skills and physical capabilities (e.g., agility) that may be transferable to team sports (Strafford et al., 2018; Wormhoudt et al., 2018). Most pertinently, based upon traditional motor skill definitions, parkour-based actions may be considered to be relatively open and outcome-oriented, with an emphasis on efficiency of movement over fixed technical models (Dvorak et al., 2017; Jabnoun et al., 2018). Although not without barriers to implementation (e.g., coach education requirements), parkour could serve as an alternative means of physical preparation for other sports (Strafford et al., 2021, 2022). This might be particularly apt in sports at the youth level where, despite widespread understanding of the importance of a long-term strategy for physical development, due to time constraints, there is likely a greater emphasis placed on sports-specific training over the development of broader athletic capabilities, which includes the development of fundamental movement skills (Liefeith et al., 2018).

Notwithstanding the potential implications of early single-sport specialisation (e.g., injury risk and burnout (DiFiori et al., 2017; Jayanthi et al., 2019), there is a necessity to acknowledge that for continued progression within a sport, eventual specialisation is required and inevitable for those who might have a preference for success over participation (Baker et al., 2021; Read et al., 2015). This is likely a key consideration within performance pathways where practice and training time is often constrained, or in training camp environments that are building towards a key competition (Fukuda et al., 2013; Owoeye et al., 2020). Indeed, the perceived relevance of an activity appears to be an important consideration in promoting compliance with implementation among coaches (Williams, Hammond, et al., 2021). Accordingly, coaches may be less likely to adhere to so-called “non-specific” training methods with their athletes (Owoeye et al., 2020).

The concept of training specificity, which implies that training content aligns with the specific demands of performance (Gebel et al., 2020), is considered to be of paramount importance in the athletic development of athletes (Issurin, 2013; Stone et al., 2022). Within the strength and conditioning field, the concept of *dynamic correspondence* has provided a basis for determining the degree of specificity of a training exercise according to its compliance to one or more of five specific criteria related to the kinetics and kinematics of sports-specific skilled actions (Stone et al., 2022; Verkhoshansky & Siff, 2009). These include the amplitude and direction of movements; accentuated regions of force production; dynamics of effort; rate and time of maximum force production; and regime of muscular work. Improvement made in a given training exercise that translates to improved sports-specific performance is therefore representative of the transfer of training (Zatsiorsky et al., 2021). An example of this is the programming of high-intensity plyometric exercises, such as bounding, to elicit changes in muscle-tendon properties of the lower limb to improve sprinting capabilities (Zisi et al., 2023).

Contemporary ideas regarding training specificity have extended beyond the purely biomechanical parameters of a training exercise (Bosch, 2018; Strafford et al., 2018). Within the strength and conditioning field, for example, the notion of *coordinative overload* has been purported to be more representative of motor behaviour and skilled performance compared to more traditional forms of overload (Bosch, 2018; Brearley & Bishop, 2019). Similarly to the donor sport concept, the notion of coordinative overload is aligned to the ecological dynamics framework and, in contrast to reductionist approaches, is considered a more integrative mechanism for skill development and performance (Bosch, 2018; Woods et al., 2020). Due to its acrobatic nature, which combines balance, coordination, muscular strength, and timing to navigate various obstacles and surfaces, parkour is suggested to be a beneficial sport that can enhance the athletic capabilities of youth basketball players (Williams, Strafford, et al., 2021). Basketball is a sport that is characterised by high frequencies of jumping and change of direction actions (Castillo et al., 2021; Ivanović et al., 2022). However, performing specific skills such as the lay-up shot, which combines various actions, is considered complex (Moradi et al., 2023). For example, the shooting player must dribble to avoid defensive players and then jump to put the ball through the basket (Miura et al., 2010). On this basis, strength and conditioning programmes for basketball players may not adequately represent the sport-specific movement requirements (Taylor et al., 2015). Therefore, the movement diversity and open-skill nature that characterise parkour actions may better represent the movement complexities observed in basketball

The parkour tic tac jump has been identified as an activity that may enhance agility (Strafford et al., 2021) and has been proposed as a beneficial exercise to improve the action capabilities of youth basketball players as part of an athletic development strategy (Williams, Strafford, et al., 2021). The tic tac requires an individual to leap towards a vertically oriented surface with one leg and push off the surface using the nearest foot into a new direction before landing back on the ground. Typically, the tic tac is performed following a run-up, requiring the performer to change momentum and generate propulsive force from the surface to redirect themselves in a new direction. Therefore, the tic tac is a jumping action that includes a multi-directional element. Although the stretch-shortening cycle is utilised to perform impulsive actions in basketball, other factors such as the surface and the direction of force production (vectors) are also crucial to jumping performance (Arede et al., 2019). Given these movement complexities, the multidirectional nature of the tic tac jump may be suited to basketball requirements, allowing players to explore their jumping capabilities beyond conventional S&C exercises. This includes applying force in different vectors with less emphasis on rigid technical models of execution (Williams, Strafford, et al., 2021).

Although the underpinning rationale for the tic tac is currently limited to theorised supposition, the running-based nature of the jumping action would appear to be relevant to basketball skills, for example, the lay-up shot, which is also regarded as a running-based jump (Pehar et al., 2017). In collegiate players, jump height and jumping index (jump height/contact time) in the lay-up shot have previously been found to be significantly higher than those for the conventional countermovement jump and repeated single- and double-leg vertical jumps (Miura et al., 2010). Elsewhere, significant correlations have been observed between the lay-up shot and countermovement jump, while larger significant correlations were revealed between the lay-up shot and the maximal running vertical jump, suggesting greater levels of specificity in the running-based jump (Pehar et al., 2017). Therefore, while the tic tac action is not identical to the lay-up, its apparent face validity to the conditions under which the lay-up shot is executed, along with its relative simplicity to implement, may encourage coaches to use it as an alternative athletic development activity based on the donor sport concept.

Although detailed examination of the donor sport concept requires intervention studies, it is also necessary to determine relevant predictor and outcome variables (e.g., biomechanical parameters) to be utilised within such studies. In addition, given that the concept of donor sports is relatively novel and the transfer of parkour training in relation to perception-action coupling is currently theoretical, quantifying the biomechanical parameters of the tic tac and lay-up shot would enhance our understanding of potential training transfer mechanisms. This could then be compared with traditional training methods. However, due to the challenges in objectively quantifying parkour-based actions, there is limited empirical evidence on the biomechanical parameters associated with these movement patterns. While evidence exists (e.g., Hernández et al., 2018) to support the use of conventional plyometric exercises such as the drop jump to improve physical capabilities in youth basketball players, the potential benefits of a parkour-based activity like the tic tac jump for developing a truly sport-specific action such as the the lay-up shot, remain to be examined.

To understand quantitively the potential value of the parkour tic tac jump to youth basketball players, the present study aimed to compare acceleration measures of the tic tac and the widely used plyometric drop jump exercise with those of the lay-up shot. For ecological validity, the use of accelerometry enabled capture of data within a ‘real-world’ youth basketball environment and unimpeded execution of the three actions of interest on the part of the participants.

Methodology

Experimental Approach to the Problem

A cross-sectional study design was used to compare accelerations between the tic tac, drop jump, and lay-up actions. All participants were required to take part in two testing sessions separated by seven days, the first of which served as a familiarisation, and the second as data collection. Following the collection of anthropometric measures (mass, height, and sitting height) using medical grade digital scales and stadiometer (Seca, Birmingham, United Kingdom), on both days, participants were required to complete a standardised warm-up that was based upon the *Starting 5* (www.basketballengland.co.uk), a neuromuscular training warm-up devised by the national governing body, Basketball England. In brief, this included pulse raiser activities involving basketball dribbling, athletic movement skills (e.g., squat, lunge, and hinge patterns), and low-intensity jumping and landing exercises.

Participants were then required to perform the three actions of interest while wearing a single inertial motion capture system (MyoMOTION 3D Motion Capture System, Noraxon Arizona, USA) with a sampling frequency of 200 Hz and based upon the sensor frame of reference. Output measures from the unit were recorded in milli-gravity (mg) and each trial was recorded separately. For each participant, the unit was positioned at the lumbar spine, above the pelvis at the L5 vertebra. All warm-up activities and testing procedures were led by the first author who is an accredited strength and conditioning coach (United Kingdom Strength and Conditioning Association).

Participants

Male and female youth basketball players recruited from a junior-level club consented to take part in the cross-sectional study. To increase the homogeneity of the population sample, participants were recruited using convenience sampling from under 14s and under 16s age groups for both males and females. Based upon inclusion criteria relating to age range, a basketball playing history of at least one year, and being free of injury that resulted in absence from playing during the six months leading up to the study, a total of 27 males (mean age 14.5 ± 1.09 years) and 12 females (mean age 14.88 years ± 1.19 years) were initially included in the study. However, because of the absence of familiarisation testing, a total of 25 participants (17 males and 8 females) were included in the final analysis. To estimate participant maturity status, anthropometric measures were entered into a sex-specific equation to predict maturity offset (Mirwald et al., 2002):

Girls: Maturity Offset (years) = -9.376 + (0.0001882 x (leg length x sitting height)) + (0.0022 x (age x leg length)) + (0.005841 x (age x sitting height)) – (0.002658 x (age x mass)) + (0.07693 x (mass by stature ratio x 100));

and

Boys: Maturity offset (years) = -9.236 + (0.0002708 x (leg length x sitting height)) + (-0.001663 x (age x leg length)) + (0.007216 x (age x sitting height)) + (0.02292 x (mass by stature ratio x 100)).

Following Peña-González et al., (2019), participants estimated to be more than six before reaching their peak height velocity were defined as pre-peak height velocity, while those estimated to be more than months after reaching their peak height velocity were defined as post-peak height velocity. Participants estimated to be within six months on either side of peak height velocity were defined as circa-peak height velocity. Within the male cohort, the estimations for maturity status revealed three individuals to be pre-peak height velocity, four to be circa-peak height velocity and one to be post-peak height velocity. Within the female cohort, all participants were classified as post-peak height velocity. Descriptive data for all participants are reported in Table 1. All experimental procedures and risks were explained fully, both verbally and in writing. Written consent and assent were obtained from the children and their parents/guardians. Ethical approval of the study was granted by the institutional research ethics committee of the authors' university and in accordance with the latest version of the Declaration of Helsinki.

[Table 1. near here]

Procedures

Firstly, participants completed the drop jump, using the technique previously described in the literature (e.g., Pauli et al., 2016; Ramirez-Campillo, Moran, et al., 2019). From a standardised box height of 30 cm, which was judged by the lead author to be appropriate across all participants, participants were required to initiate the drop jump from an upright position with their toes aligned to the box's edge. From this position, participants were instructed to drop to the floor and, upon ground contact, to *"jump as high as possible as quickly as possible*". Following three practice jumps, participants were required to complete three drop jump trials separated by ~20 seconds. Any participants not able to perform the drop jump using the specified technique, as judged by the first author, were removed from the analysis. Specifically, data from participants not dropping appropriately from the box's edge, and participants not being able to generate a fast take-off, were removed from the analysis.

Following the drop jump trials, participants completed the parkour-style tic tac action against a 'Reversaboard*'* (Eveque Leisure Equipment Ltd, Cheshire, England), constructed of solid plywood and specifically designed to be placed against a wall for indoor athletic activities. Using their preferred 'pushing' leg, participants were required to start from a standardised position measured at 45° and 3 m from the position of the Reversaboard, from where they were instructed to use approach steps towards the board and then propel from the ground to the board before pushing off from the board with the ball of their foot to gain "as much height and distance as possible", before landing back on the floor (Figure 1). Participants were instructed to gain as much height and distance from the board as possible. A total of three trials separated by ~20 seconds were recorded for analysis.

[Figure 1. near here]

Finally, using a ball size appropriate to their respective age group (size 6-7) participants were required to complete three lay-up shots, using their preferred shooting side, which corresponded with the preferred take-off limb utilised in the tic tac. For each trial, the starting position was similarly standardised to the tic tac, with a 45° and 3-m starting line measured from underneath the basketball hoop. Participants were instructed to execute a lay-up shot "*as they would in a typical basketball practice"* though the outcome of the shot was not recorded. Each lay-up trial was separated by ~20 seconds.

Data Analysis

Raw data for each trial for the three jumping actions were extracted and initially processed using Microsoft Excel (Microsoft Office, 2023). Data for all jumps and respective trials was filtered with 4th order low-pass Butterworth filter with a cut-off frequency of 50 Hz (Simons & Bradshaw, 2016). To account for the accelerometer unit being calibrated to the device's reference frame, the sum-vector was calculated (equation 1) to provide the maximum resultant acceleration (a_g). These values were also converted from mg to g for subsequent analyses.

$$a_g = \sqrt{((x^2) + (y^2) + (z^2))} \qquad \text{(equation 1)}$$

(Howard et al., 2014)

Statistical analysis of the processed data was undertaken using the statistical analysis software, JASP, version 0.18.3.0 (Amsterdam, Netherlands). All measures were tested for normality using the Shapiro-Wilk test. For data found to be normally distributed, separate Bayesian one-way repeated measures ANCOVA tests were used to evaluate the effects of action on a_g, using sex and maturation status as covariates. Accordingly, the null hypothesis was that there would not be strong evidence for differences in maximum acceleration between the jumping actions, while the alternative was that there would be strong evidence of differences in favour of the tic tac. Where strong evidence of differences was revealed, post-hoc comparisons were performed using Bayes factor comparisons to identify which jumping actions these differences belonged to. In accordance with Andraszewicz et al. (2015), the Bayes factor was interpreted in terms of discrete categories of evidential strength.

Further, to provide a practical appreciation of the results, between-action effects sizes for a_g were calculated using a pooled standard deviation for males and females and interpreted as 'small', 'medium', and 'large' in accordance with Cohen's *d* guidelines (Lovakov & Agadullina, 2021).

Results

Mean values for a_g are displayed in Figure 2. The results of the Bayesian one-way repeated measures ANCOVA tests for a_g (Table 2) revealed extreme ($BF_{10} > 100$) evidence for all models that included the jump test when compared to the Null model. The jump test + sex model was found to be the best fitting. However, despite the BF_M being found to be four times more likely than the second-best model (the jump test alone), the analysis of the effects of sex as a predictor did not reveal conclusive evidence to support its inclusion or exclusion. The Bayes Factors for maturation status showed anecdotal evidence against an inclusion effect ($BF_{10} = < 1.00$). The effects of the different predictor variables and 95% credible intervals are displayed in Table 3. The tic tac was found to have a positive effect on the model compared with the drop jump, which was found not to have an effect, and the lay-up that revealed a negative effect. The post hoc comparisons revealed that the tic tac produced greater acceleration than the drop jump and lay-up, while the drop jump produced greater acceleration compared to the lay-up (Table 4).

In the ES analyses, a large effect size was found between a_g for the tic tac and the drop jump, and between the tic tac and the lay-up in the male cohort. The comparison between the drop jump and the lay-up in the male cohort also revealed a large effect size. Similarly, in the female cohort, a large size was found between the tic tac and the drop jump, and the tic tac compared to the lay-up a_g values. In contrast to the male cohort, however, the effect size between the drop jump and lay-up was small.

[Table 2. near here]

[Figure 2. near here]

[Table 3. Near here]

[Table 4. Near here]

[Table 5. Near here]

Discussion

The purpose of our study was to evaluate maximum acceleration in the parkour-style tic tac jump and drop jump in comparison to the basketball lay-up shot in youth basketball players. The tic tac was found to produce higher maximum propulsive acceleration compared to both the drop jump and the lay-up, which was observed irrespective of sex or maturational status. Considering these findings, this study indicates that the tic tac may be utilised by both male and female youth-level basketball players to express maximal propulsive acceleration.

This was further highlighted by large effect size values revealed between the tic tac and the other two jumping-based actions. Accordingly, this study provides evidence towards the integration of parkour-based actions in the youth athletic development training of youth basketball players.

Despite the long-term strategy for the physical development of young athletes emphasising broad athletic capabilities, the perceived relevance of the training activities by coaches remains important (Owoeye et al., 2020; Williams, Hammond, et al., 2021). Moreover, conventional strength and conditioning training approaches have been questioned for not representing the demands of basketball (e.g., the actions that occur in the frontal plane) (Taylor et al., 2015; Williams, Strafford, et al., 2021). However, contemporary strength and conditioning concepts, such as coordinative overload and those based on the ecological dynamics framework, are purported to be more representative of motor behaviour and skilled performance compared to the traditional forms of mechanical overload (Bosch, 2018; Brearley & Bishop, 2019).

From the ecological dynamics perspective, parkour has been proposed as a donor sport for the athletic development of youth basketball players (Williams, Strafford, et al., 2021). Through this lens, the use of parkour-style activities, such as the tic tac, have been purported to benefit the athletic development of young team sports athletes, particularly in relation to agility-related qualities (Strafford et al., 2018, 2021). In particular, through the ecological dynamics lens, the human body is regarded as a complex dynamical system, and motor skills are considered to emerge out of the interaction between the constraints of the performer's capabilities, the specific motor task, and the surrounding environment (Davids et al., 2013; Witt & Riley, 2014).

Within sports-specific contexts such as basketball, interacting task and environmental constraints require players to produce diverse and adaptable skills and movement patterns

(Renshaw et al., 2022). Accordingly, the multi-directional nature of the tic tac jump may contribute to improved acceleration in multiple planes of motion, facilitating greater transfer of training to the 'open skill' context of basketball, where skills are performed with a degree of unpredictability (Wang et al., 2013). Indeed, the tic tac has been previously suggested as an exercise to target athletic capabilities relating to the coupling of movements at various speeds (Strafford et al., 2021). Such characteristics appear to relate to basketball shooting, which has previously been shown to correlate with both countermovement jump and change of direction capabilities (Pojskic et al., 2018). Therefore, it is plausible, that these findings would extend to the lay-up shot, which requires the execution of a specific pattern of footwork combined with a subsequent jump to the basket (Candra, 2018; Wang et al., 2023).

However, when considering our results from an ecological dynamics perspective, it is also important to acknowledge that in a complex dynamical system observed effect size magnitudes between different actions may not necessarily transfer in a linear fashion. This especially important when considering the complex sports skills such as the lay-up, executed within the context of a basketball game. Such non-linear effects have been previously highlighted by Arede et al. (2022) which, following a 10-week strength training programme revealed a large effect size for the observed pre-post differences in peak acceleration displayed by youth players within a simulated basketball game. However, despite utilising the training intervention targeting optimal power output using a loaded back squat, the observed effect size for the pre-post countermovement jump was small. Accordingly, in the current study, the larger effect size values observed for the tic tac may not necessarily translate to detectable linear improvements in the performance of the lay-up under game-specific conditions.

Of further consideration, based upon perception-action coupling, the use of the ball within the lay-up shot may have also altered the dynamics of the action, with potential implications for the levels of acceleration produced. Indeed, including a ball-catching task in the execution of the single leg drop jump has been found to increase movement variability in youth basketball players, although it did not alter jump height or ground contact time in comparison to the no ball condition (González-Millán et al., 2024). Therefore, it is possible that the perceptual differences between the jumping actions could influence the respective acceleration outputs and the degree of transfer between the motor tasks. Nonetheless, the results of our study provide an objective basis for further investigation of the tic tac as an action that could donate to the development of athletic capabilities of youth basketball players.

Despite not being a primary concern in the athletic development models of youth populations, exercises with high sports-specificity are more likely to be implemented and adhered to by basketball coaches compared to those considered to be less specific (Owoeye et al., 2020; Williams, Hammond, et al., 2021). Coaches of youth basketball players have been found to be reluctant to implement athletic development-based skills and activities within their practices due to time constraints (Owoeye et al., 2020; Williams et al., 2021). As a consequence. youth players risk underdeveloping diverse movement skills and physical capabilities during critical periods when they may develop motor skills more readily due to high neural plasticity (Myer et al., 2015). Indeed, during what is termed a golden period of motor learning (Williams, Ramirez-Campillo, et al., 2021), it is suggested that the development of broad and diverse fundamental movement skills should be emphasised to equip youth with greater movement capabilities rather than limiting skill development to a single sport (DiFiori et al., 2017). Therefore, the time-efficiency of strength and conditioning training is imperative in youth sports, with the greatest proportion of dedicated training being allocated to sports-specific development (Read et al., 2016; Till & Baker, 2020).

From a motor learning perspective, beyond the single familiarisation session, the tic tac and drop jump were novel skills for all participants to perform. Therefore, the larger acceleration observed in the tic tac compared to the drop jump suggests that the tic tac may be more time-efficient to include in the athletic development programmes of youth basketball players. The relative simplicity of the tic tac, coupled with the limited requirement of training equipment, enables the exercise to be easily implemented in typical basketball playing environments. In turn, the tic tac might present a time efficient and effective activity that can contribute to the development of broader movement skill and athletic capabilities. While this would need to be confirmed through further investigations, including longer skill development periods involving the tic tac and drop jump, and through intervention studies examining the training effects of these actions, it is particularly relevant for its potential adoption by coaches of youth basketball players. Due to the movement characteristics of the tic tac (e.g., combined running and multi-directional jumping), coaches of youth basketball players may be more likely to implement the exercise within their practice.

Within the field of strength and conditioning, the application of mechanical overload is understood to be necessary to elicit training adaptations that can enhance sport performance (Brearley & Bishop, 2019). From a classical strength and conditioning training perspective, for training adaptations transfer successfully to sports performance, those adaptations must exhibit a high degree of mechanical specificity to the target activity (Verkhoshansky & Siff, 2009; Zatsiorsky et al., 2021). According to the principle of dynamic correspondence, an exercise is considered specfic if it overloads at least one of its five biomechanical-based criteria associated with the target activity (Suarez et al., 2019; Verkhoshansky & Siff, 2009). Therefore, rather than overloading of an entire movement skill, the training activity is considered to target “local specificity” (Brearley & Bishop, 2019). Given that the lay-up has been previously shown to relate to speed and strength qualities

(Miura et al., 2010; Zhu et al., 2020), it is reasonable to infer that the utilisation of the tic tac and drop jump as training exercises could provide mechanical overload to the lower limb in relation to the production of propulsive acceleration specific to the jumping element of the lay-up. Moreover, based upon the dynamic correspondence concept, the larger magnitudes of acceleration in the tic tac and drop jump appear to conform to the rate and time of maximum force production criterion (Suarez et al., 2019). However, the multi-directional characteristics of the tic tac may overload propulsive acceleration capabilities in different planes of motion to a greater extent than the drop jump, which is typically utilised to improve impulse in the vertical plane (Dello Iacono et al., 2017). Nonetheless, given that acceleration is representative of the rate of change in velocity and is proportional to force, it is plausible that both jump actions could be utilised to enhance the required motor qualities relating to rate and time of maximum force production specific to the lay-up shot.

To add further context to our findings, the observed differences in accelerations between the tic tac and the drop jump are not surprising given the lower magnitude of ground reaction force likely experienced in the contact phase of the tic tac and corresponding demands on the musculature of the lower limb. Execution of the drop jump requires the athlete to decelerate their body mass by generating eccentric force before re-orientating as rapidly as possible in an upward direction (Struzik et al., 2016; Xu et al., 2023). Unlike the drop jump, which generates a high-ground reaction force due to the full mass of the individual falling under gravity, the tic tac action involves a lateral change of direction that requires a lower magnitude of ground reaction force (Pedley et al., 2017).

Another explanation for the maximal propulsive acceleration resulting from the drop jump might relate to the drop height, which was fixed at 30 cm for all participants regardless of body size, athletic capability, or sex. Ground contact time and subsequent jump heights have previously been found to be influenced by the drop height (Addie et al., 2019; Ramirez-

Campillo, Alvarez, et al., 2019). In general, drop heights are typically between 20-50 cm, with the greater heights presenting increased ground reaction forces and, in turn, larger eccentric demand on the muscles of the lower limb (Pedley et al., 2017; Prieske et al., 2019; Ruffieux et al., 2020). Of pertinence, compared to adults, youths' musculotendinous tissue is more pliable, which can reduce the efficiency with which they utilise the stretch-shortening cycle (Lazaridis et al., 2010; Leukel et al., 2022). Therefore, in the absence of measures of ground contact times, the fixed 30 cm drop used in our study was deemed to be appropriate for the cross-sectional design, and age range and sex of the participants. Indeed, this was further vindicated by our finding that the maturation status of the participants did not appear to have any significant effect. On this basis, the tic tac may be regarded as an activity that may benefit youth basketball players, irrespective of their age or maturity status. Furthermore, with inconclusive evidence for an effect of sex in the results, despite differences that emerge between males and females at the onset of puberty, the tic tac may be beneficial for both sexes.

However, caution must be exercised given the small number of female participants in our study, all of whom were estimated to be post-peak height velocity. Nonetheless, our results appear interesting when considered against studies that have investigated the effects of plyometric exercises across different stages of maturation (Moran et al., 2017, 2019). Such studies have revealed that the effectiveness of plyometric training varies based upon stage of maturation, which differs between males and females. For example, plyometric exercise has been found to be more effective in younger females (< 15 years of age), potentially owing to increased levels of fat mass in post-pubescent girls (Moran et al., 2019). In contrast, males have been found to benefit more greatly from plyometric training both pre- and post-peak height velocity, with post-peak height velocity trainability suggested to be related to greater force capabilities owing to increased muscle tissue (Moran et al., 2017). Our findings, however, suggest that the tic tac may enable adolescent females to express greater propulsive acceleration than the drop jump. In turn, the tic tac may be utilised as an exercise to increase propulsive outputs.

Although our findings provide some interesting insights relating to the use of the parkour-style tic tac action, there are important limitations to consider. Firstly, our study compared the acceleration between jumps without addressing ground reaction force produced in the three jumping actions. The inclusion of ground reaction force would have provided greater insights into the kinetic differences between the tic tac, drop jump, and lay-up, which would have also accounted for ground contact time and impulse. Secondly, using the reactive strength index to determine the optimal jump height based on differences in eccentric capabilities may have elicited different outcomes with respect to the drop jump. Thirdly, measures of the lay-up skill, both with and without a ball, may have provided valuable comparisons of acceleration outputs without the constraints imposed by the executing the basketball shot. Finally, while the use of the Mirwald equation is widely utilised youth-related research, it only provides an estimate of maturity offset. Therefore, the maturity status of the participants in our study may have varied due to the standard errors of the equation.

Conclusions

Training specificity and the transfer of training exercises is a central consideration in the preparation of athletes. However, this is also somewhat at odds within the athletic development strategy of youth athletes, which typically recommends the enhancement of fundamental movement skills and general physical capabilities. In the context of the principle of dynamic correspondence, the greater maximal propulsive acceleration observed in the tic tac indicates that it may provide specific overload to acceleration capabilities, which may be pertinent to the lay-up shot. From an ecological dynamics standpoint, where parkour has been proposed as a donor sport for the athletic development of youth team sport athletes to enhance agility, the tic tac may offer young basketball players a multi-directional jumping action that more closely represents the dynamics of basketball-specific actions, which occur with a high degree of unpredictability and variability. Importantly, the tic tac may be more readily implemented by coaches of youth basketball players, contributing to their athletic development.

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