Effectiveness of adding single leg hop training to wobble board training in improving dynamic balance and lower limb explosive power in 13–14-year-old basketball players: A randomized controlled trial

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ABSTRACT

Background: Dynamic balance and lower-limb explosive power are important for youth basketball performance. Wobble board training may improve postural control, while single leg hop exercises may provide additional benefits through dynamic unilateral loading. However, evidence regarding their combined effects in adolescent basketball players remains limited.
Objective: To determine whether adding single leg hop training to wobble board training produces greater improvements in dynamic balance and lower-limb explosive power than wobble board training alone in 13–14-year-old basketball players.
Methods: This randomized controlled trial included 40 players randomly allocated (1:1) to wobble board training (control; n = 20) or combined wobble board and single leg hop training (experimental; n = 20). Both groups trained for six weeks, three 30-minute sessions per week. Dynamic balance (primary outcome) and lower-limb explosive power (secondary outcome) were assessed using the Y-Balance Test (YBT) and Vertical Jump Test (VJT), respectively. Within- and between-group changes were analysed using paired- and independent-samples t-tests ($\alpha = 0.05$).
Results: All participants completed the intervention. Both groups improved significantly in YBT and VJT performance ($p < 0.001$). The experimental group showed greater improvements in YBT (mean change: 15.32 vs 5.23 cm; mean difference = 10.08 cm; 95% CI [7.73, 12.43]; $p < 0.001$; d = 2.75) and VJT (5.75 vs 0.82 cm; mean difference = 4.94 cm; 95% CI [4.22, 5.66]; $p < 0.001$; d = 4.41).
Conclusion: Adding single leg hop training to wobble board training produced greater improvements in dynamic balance and lower-limb explosive power. However, the findings do not establish an isolated single-leg-hop effect or injury-prevention benefit.

Keywords: dynamic balance, explosive power, single leg hop, wobble board, youth basketball.

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INTRODUCTION

Basketball is a team sport that demands a combination of technical skill and high physical capacity. Players must repeatedly perform complex movements such as vertical jumping to contest rebounds, sudden acceleration and deceleration, and explosive changes of direction within a dynamic playing environment. Two physical components are particularly critical to these movements: dynamic balance and lower limb explosive power. Dynamic balance is the ability to maintain postural stability while moving or when subjected to positional perturbation, and is essential for landing safely after a jump, executing pivots, and changing direction without losing body control. Reduced performance on dynamic balance screening, such as a low composite reach score or a marked side-to-side asymmetry on the Y-Balance Test, has been linked prospectively to a higher likelihood of lower-extremity injury in basketball and other sports (Plisky et al., 2006; Butler et al., 2013). Epidemiological reviews also indicate that the lower extremities account for a substantial proportion of basketball injuries, with ankle and knee injuries among the most common presentations (Aarts et al., 2021; Liu et al., 2025). This makes dynamic balance both a determinant of on-court performance and a modifiable target for injury-prevention programs. Explosive power, the second component, is the ability of the muscles to generate a high level of force in a very short time, and it underpins the take-off for rebounding and blocking, the first steps of a fast break, and the rapid deceleration needed to change direction safely.

The 13–14-year age group was selected deliberately because it coincides with a critical and complex phase of biological development. Early adolescence typically overlaps with the onset of puberty and the adolescent growth spurt, during which stature, limb length, and body mass increase rapidly and often unevenly, temporarily displacing the body's centre of gravity and altering the length and leverage of the limb segments (Malina et al., 2015). These anthropometric changes can transiently disturb postural control and coordination, because the neuromuscular system must continually recalibrate to a body whose proportions are shifting. At the same time, chronological age is an imperfect marker of development at this stage: two players of the same age may differ substantially in maturational status, and therefore in body size, muscle mass, and motor capacity (Malina et al., 2015). Longitudinal evidence indicates that motor and physical fitness qualities—including strength, speed, agility, and explosive power—change markedly between 13 and 15 years and are closely interrelated with anthropometric growth during this window (Lloyd et al., 2014). Because chronological rather than biological age was used to define the sample, the participants are best regarded as a chronologically defined early-adolescent group that may encompass a range of maturational stages. This developmental context makes early adolescence both a period of heightened trainability and one in which structured, well-supervised training is particularly relevant, as programme design should account for growth and maturation rather than age alone (Lloyd et al., 2014; Granacher & Behm, 2023).

A preliminary observation conducted by the researcher at a youth basketball club in Denpasar, Indonesia, indicated that 62% of players aged 13–14 years exhibited balance deficits and 48% demonstrated lower-limb explosive power below the preliminary reference standard used in the observation. These figures were recorded as part of the preliminary observation reported in the thesis and are presented here as contextual observations rather than as baseline outcome data for the trial. Such limitations are especially relevant during the developmental phase described above, in which rapid growth, shifting body proportions, and an immature neuromuscular system may interact with postural control and efficient muscle recruitment.

Two training modalities have been widely investigated for addressing these deficits: wobble board training and single leg hop training. Wobble board training is an instability-based exercise that continuously stimulates mechanoreceptors in the joints and stabilising muscles, producing adaptations in neuromuscular coordination, proprioceptive sensitivity, and postural control. A home-based balance-training program using a wobble board has been shown to improve balance and reduce sports-related injuries in healthy adolescents (Emery et al., 2005), and wobble board training has been reported to improve balance, ankle proprioception, and single-leg jump-landing parameters (Taghavi Asl et al., 2022). Single leg hop training, a unilateral plyometric exercise, works through a complementary mechanism by exploiting the stretch-shortening cycle of the lower limb muscles—the eccentric–transition–concentric sequence that enhances the capacity of muscle fibres to generate force rapidly, thereby increasing power output (Malisoux et al., 2006). Because it is performed on a single leg, this exercise simultaneously imposes a dynamic balance demand.

Although each modality has been studied on its own, they target the two deficits through different physiological routes, which is the basis for combining them. Wobble board training mainly challenges the sensory and reflexive components of postural control, refining how quickly and accurately the athlete detects and corrects deviations in body position; this is well suited to improving dynamic balance but provides only a limited stimulus for maximal force production. Single leg hop training, by contrast, imposes brief, high-intensity loading that emphasises the rate at which force can be produced, the primary requirement for explosive movements such as jumping and rapid change of direction. In a growing athlete, whose nervous system is still refining motor patterns, exposure to both types of stimulus within the same program may allow gains in stability and power to develop together rather than in isolation. This rationale is consistent with reviews reporting that combining balance and strength or power training yields broader improvements in youth athletes than either component alone (Granacher & Behm, 2023; Filipa et al., 2010).

Combining these two modalities offers a more comprehensive approach based on their complementary physiological demands and grounded theoretically in the principle of Specific Adaptation to Imposed Demands. Wobble board training builds a foundation of neuromuscular stability, while single leg hop training provides an explosive stimulus that may exploit this foundation. Evidence from youth training studies suggests that combining or sequencing balance and plyometric exercises can influence adaptations in balance and muscular fitness; however, the optimal within-session sequence may depend on the training objective and exercise characteristics (Granacher & Behm, 2023). In the present protocol, single leg hop was deliberately performed before wobble board exercise to preserve the quality of the explosive movement before fatigue from the stability task. Plyometric jump training, in particular, has been shown in meta-analyses to improve jumping performance, sprint speed, change-of-direction speed, balance, and muscle strength in basketball players irrespective of sex and age (Ramirez-Campillo et al., 2022), and to enhance physical fitness across youth of differing maturity status (Ramirez-Campillo et al., 2023), combined balance and plyometric training has likewise improved athletic performance in adolescent basketball players (Bouteraa et al., 2020), and short-term plyometric training improves physical fitness in early pubertal male basketball players (Zribi et al., 2014; Moran et al., 2017). However, studies specifically testing the combination of wobble board and single leg hop training in 13–14-year-old basketball players remain scarce; much existing evidence derives from adult, older adolescent, or higher-level athletes. The novelty of this study lies in testing this specific combined protocol in early adolescent players using a controlled design. The purpose was to determine whether adding single leg hop training to wobble board training produces greater improvements in dynamic balance and lower limb explosive power than wobble board training alone, providing coaches and clinicians with evidence to inform time-efficient conditioning for young athletes.

METHODS

Study Design and Participants

This study used a true experimental pre-test–post-test control group design. Participants were 40 basketball players aged 13–14 years drawn from a single youth club in Denpasar, Bali, Indonesia. Eligible players were first identified from the club membership and screened against the eligibility criteria using purposive sampling. Inclusion criteria were: chronological age 13–14 years, active club membership with at least 75% attendance in the preceding three months, no lower-extremity musculoskeletal injury within the preceding six months, and written parental or guardian informed consent. Exclusion criteria were pathological balance disorders, concurrent participation in another intensive training program, and acute illness at enrolment. All 40 enrolled participants completed the six-week program without drop-out (Figure 1).

Trial activities were conducted at the participating youth basketball club in Denpasar, Bali, from March to May 2026. Pre-testing was conducted on 23–27 March 2026, the six-week intervention ran from 30 March to 9 May 2026, and post-testing was conducted on 12–14 May 2026. This trial was not prospectively registered in a publicly accessible clinical trial registry before participant enrolment. The absence of prospective registration is acknowledged as a limitation of the study and should be considered when interpreting the findings.

After eligibility screening and receipt of written parental or guardian consent, the 40 eligible participants were randomly assigned to the experimental or control group in a 1:1 ratio using a simple lottery-drawing procedure. Forty identical folded slips were prepared, consisting of 20 slips labelled “Experimental” and 20 slips labelled “Control.” The slips were mixed thoroughly in an opaque container before drawing. Each participant drew one slip without replacement, and the group assignment was determined according to the label on the selected slip. The allocation procedure was conducted by the principal researcher with the assistance of a research assistant. Because no independent allocation administrator or formal allocation-concealment mechanism was used, such as sequentially numbered opaque sealed envelopes or central randomization, allocation concealment could not be ensured. Outcome assessment was subsequently performed by a research assistant who was blinded to group assignment. The authors certify that the study was conducted in accordance with the ethical standards of the Declaration of Helsinki and that a parent or guardian of each participant signed a consent form. Biological maturation was not formally assessed; chronological age was used to define the sample, and this is acknowledged as a limitation.

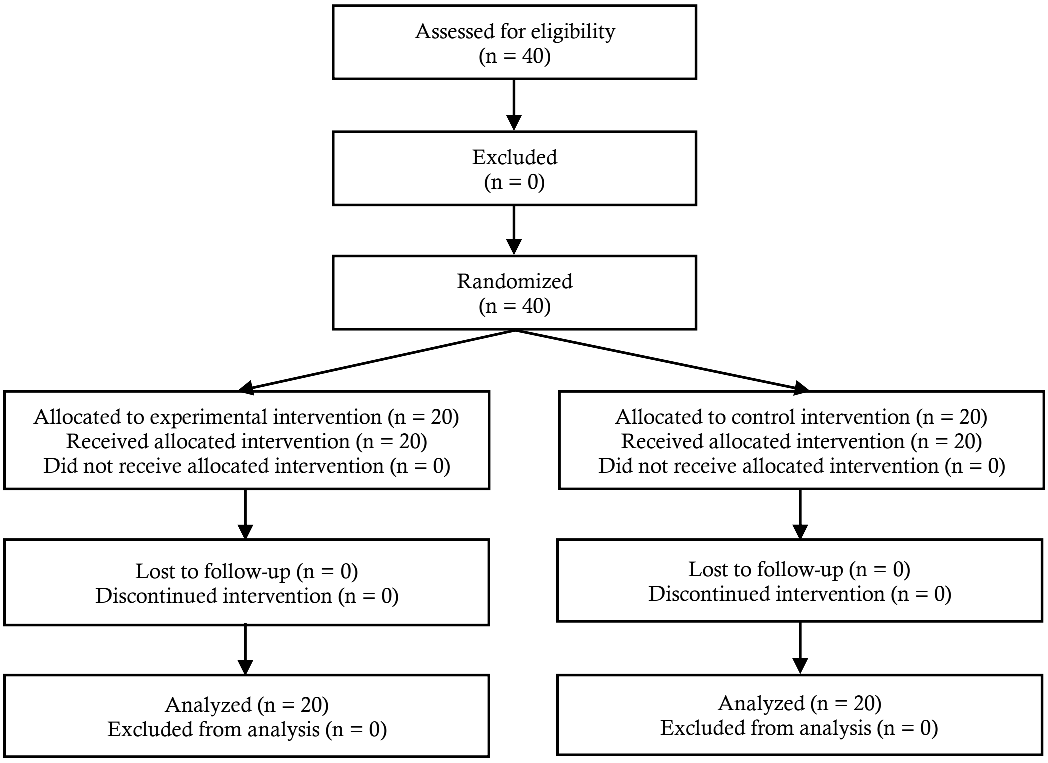

Figure 1. CONSORT Flow Diagram of Participant Recruitment, Allocation, Follow-Up, and Analysis

Sample size was calculated based on the primary outcome, dynamic balance assessed using the Y-Balance Test (YBT), using the Power Calculation for One Comparison (POCO) formula. The calculation assumed a two-tailed significance level (α) of 0.05, statistical power of 0.80, an expected between-group difference (Δ) of 5 cm, and a standard deviation (SD) of 5 cm, corresponding to a variance (σ^2) of 25 cm^2. Based on these parameters, the minimum required sample size was 16 participants per group. To account for an anticipated attrition rate of up to 25%, the target sample size was increased to 20 participants per group, resulting in a total target sample of 40 participants.

Ethical approval statement

The study received approval from the Health Research Ethics Committee, Faculty of Medicine, Universitas Udayana, with the assigned approval number 2534/UN14.2.2.VII.14/LT/2026 (Protocol No. 2026.02.1.0894).

Primary and Secondary Outcomes

The primary outcome of this study was dynamic balance, assessed using the Y-Balance Test (YBT). The YBT was selected as the primary outcome because the intervention was primarily designed to improve dynamic postural control through wobble board training, with single leg hop training providing an additional unilateral dynamic-stability stimulus. YBT performance was assessed before and after the six-week intervention using the standardized testing procedure described below.

The secondary outcome was lower-limb explosive power, assessed using the Vertical Jump Test (VJT). The VJT was used to determine whether the addition of single leg hop training produced improvements in explosive lower-limb performance beyond those observed with wobble board training alone. Both outcomes were assessed at baseline and 48 hours after completion of the six-week intervention by an assessor blinded to group allocation.

Research Instruments

Dynamic balance was assessed using the Y-Balance Test (YBT). Participants performed reaches in the anterior, posteromedial, and posterolateral directions while maintaining a single-leg stance. Each reach direction was performed for three trials, with a 30-second interval between trials, and the mean of the three successful trials was calculated for each direction. Reach performance was then summarized across the three directions and expressed in centimetres. The procedure was repeated for the contralateral limb, and the mean value across both limbs was used for analysis.

Explosive power was assessed using the Vertical Jump Test (VJT). Jump height was recorded as the difference between the maximal jump reach and the standing reach, taken as the highest of three maximal attempts with brief rest between trials; participants performed a vertical jump from a standing position without a run-up and were instructed to reach maximally at the apex. Field-based vertical jump procedures of this kind are established, reliable, and valid indices of lower-limb explosive power (Comyns et al., 2023; Petrigna et al., 2019). Standardised verbal instructions and demonstrations were provided, and outcome assessors were blinded to group allocation.

Test-retest reliability was not re-established within the present cohort. Therefore, previously published evidence was used to support the measurement procedures. For the Lower Quarter Y-Balance Test in adolescents, published studies report predominantly good-to-excellent reliability and MDC95 values of approximately 4.90–16.10%, depending on age and reach direction (Linek et al., 2017; Schwiertz et al., 2019). For vertical jump assessment, adolescent and youth samples have demonstrated good between-session reliability, although values depend on the jump protocol and measurement device (Thomas et al., 2017; Bogataj et al., 2020).

Intervention Protocol and Progression

The intervention lasted six weeks, with three sessions per week for both groups. Each session lasted 30 minutes and followed an identical structure: a 10-minute warm-up, 15 minutes of core training (the group-specific intervention), and a 5-minute cool-down. The warm-up and cool-down were the same for both groups. The experimental group completed single leg hop training first and then, as a separate block within the same session, wobble board training; single leg hop was placed before wobble board work so that the more demanding explosive drills were performed before any balance-related fatigue accumulated. The control group performed wobble board training only during the 15-minute core-training block. The two programmes were matched for session duration, weekly frequency, total intervention length, warm-up, and cool-down. The principal between-group difference was the inclusion of single-leg hop and additional jumping-based exercises in the experimental programme, whereas the control programme consisted of wobble-board-based exercises without a comparable jumping stimulus.

Table 1. Detailed Six-Week Training Programme for the Experimental Group (Wobble Board + Single Leg Hop)

Week	Phase	Exercise	Sets	Reps / Duration	Rest	Intensity
1–2	Technique mastery	Single leg hop (forward)	2	8 hops/leg	45 s/set	Low
1–2	Technique mastery	Wobble board single-leg static stance	2	20 s/leg	20 s/set	Low
3–4	Volume progression	Single leg hop (forward + lateral)	3	10 hops/leg	30 s/set	Moderate
3–4	Volume progression	Wobble board + free-foot movement (front/side)	3	30 s/leg	15 s/set	Moderate
3–4	Volume progression	Small hops on wobble board	2	8 hops/leg	45 s/set	Moderate
5–6	Intensity & complexity	Multiplanar single leg hop (front + lateral + diagonal)	3	12 hops/leg	25 s/set	High
5–6	Intensity & complexity	Wobble board + random-direction + eyes closed	3	40 s/leg	15 s/set	High
5–6	Intensity & complexity	Hops on wobble board (increased speed)	3	10 hops/leg	30 s/set	High

Note. In every session single leg hop was performed before wobble board work. Each 30-minute session comprised a 10-minute warm-up, 15 minutes of core training (the exercises above), and a 5-minute cool-down (static stretching, 1 set × 15–30 s per movement). Target RPE (Borg 6–20): weeks 1–2, 11–13; weeks 3–4, 13–15; weeks 5–6, 15–17.

Table 2. Detailed Six-Week Training Programme for the Control Group (Wobble Board Only)

Week	**Phase**	**Exercise**	**Sets**	**Reps / Duration**	**Rest**	**Intensity**
1–2	Technique mastery	Wobble board single-leg static stance	2	20 s/leg	20 s	Low
1–2	Technique mastery	Wobble board double-leg stance + weight shifting	2	30 s/set	20 s	Low
3–4	Volume progression	Wobble board single-leg + free-foot movement (three directions)	3	30 s/leg	15 s	Moderate
3–4	Volume progression	Wobble board + partner ball toss/catch	3	20 s/leg	20 s	Moderate
5–6	Intensity & complexity	Wobble board single-leg + eyes closed	3	40 s/leg	15 s	High
5–6	Intensity & complexity	Tandem stance using two wobble boards	3	30 s/position	20 s	High

Note. Each 30-minute session comprised a 10-minute warm-up, 15 minutes of core training (the exercises above), and a 5-minute cool-down (static stretching identical to the experimental group). Warm-up and cool-down were identical for both groups. Target RPE (Borg 6–20): weeks 1–2, 11–13; weeks 3–4, 13–15; weeks 5–6, 15–17.

Both programmes were delivered under the direct supervision of the principal researcher and trained assistants and progressed across three consecutive two-week phases: Phase 1 (weeks 1–2) emphasised technique mastery, Phase 2 (weeks 3–4) emphasised progression of training volume, and Phase 3 (weeks 5–6) emphasised progression of intensity and movement complexity. Progression to the next phase was permitted only when a participant was able to complete all sets of the preceding phase with correct technique in at least the final two sessions of that phase. Training intensity was prescribed using the Borg 6–20 Rating of Perceived Exertion (RPE) scale as a practical guide for exercise progression. Target RPE ranges were set at 11–13 during weeks 1–2, 13–15 during weeks 3–4, and 15–17 during weeks 5–6, corresponding to the progressive increase in training difficulty across the intervention phases. RPE was used to guide the prescribed training intensity and was not treated as a study outcome or included in the statistical analyses. The complete set, repetition/duration, rest-interval, and intensity parameters prescribed for each group in each phase are presented in Table 1 (experimental group) and Table 2 (control group). In the experimental group, single leg hop was performed before wobble board work in every session so that explosive-movement quality would not be compromised by stabiliser fatigue accumulated during the balance tasks. Warm-up and cool-down were identical for both groups. Potential confounding factors, including nutritional status, sleep quality, and out-of-program physical activity, were monitored informally throughout the intervention to support protocol implementation; however, these variables were not analysed as study outcomes. Post-testing was conducted 48 hours after the final session, using the same protocol, instruments, and blinded assessor as the pre-test.

Participants were monitored throughout each training session for adverse events, including pain, musculoskeletal injury, excessive fatigue, or other exercise-related complaints. Any adverse event occurring during or following the intervention sessions was documented by the research team.

Data Analysis

Data were analysed using SPSS version 26.0. Descriptive statistics were calculated for all variables and are presented as mean ± standard deviation (SD). The Shapiro–Wilk test was used to assess the normality of change-score distributions, and Levene's test was used to assess the homogeneity-of-variance assumption for the between-group change-score comparisons. Within-group pre–post changes were analysed using paired-samples t-tests. Between-group differences in intervention response were analysed using independent-samples t-tests applied to change scores (post-intervention minus baseline). Effect sizes were reported as Cohen's d, and 95% confidence intervals were reported for between-group mean differences. Statistical significance was set at $\alpha = 0.05$.

RESULTS

Forty participants (20 per group) completed the six-week intervention without attrition and were included in the analysis. Baseline and post-intervention descriptive statistics for the Y-Balance Test (YBT) and Vertical Jump Test (VJT) are presented in Table 3. At baseline, mean YBT scores were 140.13 ± 6.19 cm in the control group and 138.24 ± 8.13 cm in the experimental group, while mean VJT scores were 30.77 ± 2.44 cm and 32.63 ± 3.69 cm, respectively. Baseline values are reported descriptively; no significance testing was performed to establish baseline equivalence between the randomized groups. No adverse events, intervention-related injuries, or exercise-related complaints requiring discontinuation of training were reported during the six-week intervention.

On the YBT, the control group improved by 5.23 cm, from 140.13 to 145.36 cm (a 3.74% increase), whereas the experimental group improved by 15.32 cm, from 138.24 to 153.56 cm (an 11.08% increase). On the VJT, the control group improved by 0.82 cm, from 30.77 to 31.59 cm (a 2.65% increase), whereas the experimental group improved by 5.75 cm, from 32.63 to 38.38 cm (a 17.62% increase). Baseline descriptive statistics for both outcomes are presented in Table 3. Paired t-tests confirmed significant within-group improvement in both groups for both outcomes (Table 4).

Table 3. Baseline and Post-Intervention Y-Balance Test and Vertical Jump Test Scores by Randomized Group

Outcome	Time point	Control (n = 20), Mean ± SD	Experimental (n = 20), Mean ± SD
YBT (cm)	Baseline	140.13 ± 6.19	138.24 ± 8.13
YBT (cm)	Post-intervention	145.36 ± 6.75	153.56 ± 8.79
VJT (cm)	Baseline	30.77 ± 2.44	32.63 ± 3.69
VJT (cm)	Post-intervention	31.59 ± 2.61	38.38 ± 4.66

Note. Values are presented as mean ± standard deviation (SD). YBT = Y-Balance Test; VJT = Vertical Jump Test.

Table 4. Within-Group Paired *t*-Test Results

Group	Variable	Mean Δ (cm)	t	df	p	Cohen's d
Control	YBT	5.23	7.654	19	<0.001*	1.71
Control	VJT	0.82	7.232	19	<0.001*	1.62
Experimental	YBT	15.32	16.31	19	<0.001*	3.65
Experimental	VJT	5.75	17.18	19	<0.001*	3.84

*Note. Δ = change score (post - pre); df = degrees of freedom; * significant at α = 0.05. Effect size: conventional large threshold > 0.8 (Cohen, 1988); values > 2.0 are described as huge following Sawilowsky (2009).*

Independent samples t-tests on the change scores confirmed that the experimental group improved significantly more than the control group for both outcomes (Table 5): the YBT change-score difference was 10.08 cm ($t(38) = 8.679$, $p < 0.001$, $d = 2.75$, 95% CI 7.73 to 12.43 cm) and the VJT change-score difference was 4.94 cm ($t(38) = 13.971$, $p < 0.001$, $d = 4.41$, 95% CI 4.22 to 5.66 cm). These effects were exceptionally large in magnitude; given the modest sample and controlled comparison, their size should be interpreted cautiously rather than as evidence that the exact magnitude would generalise to other populations.

Regarding measurement error, the observed YBT improvement in the experimental group (11.08%) was considered in relation to published adolescent MDC95 values for Lower Quarter Y-Balance Test performance (approximately 4.90–16.10%, depending on age and direction), while the control-group change (3.74%) is below that published range. Because the present study used an aggregated bilateral YBT outcome and the published MDC values vary by age and reach direction, these comparisons are not exact and should not be interpreted as definitive evidence of change beyond measurement error. A directly comparable established MDC for the specific Vertical Jump Test protocol used here was not identified;

therefore, the VJT findings are interpreted primarily as between-group treatment effects rather than as proof that change exceeded a protocol-specific MDC.

Table 5. Between-Group Independent t-Test Results (Change Scores)

Variable	Δ Exp. (cm)	Δ Control (cm)	Difference (cm)	t	df	p	Cohen's d	95% CI for difference (cm)
YBT	15.32	5.23	10.08	8.679	38	<0.001*	2.75	7.73 to 12.43
VJT	5.75	0.82	4.94	13.971	38	<0.001*	4.41	4.22 to 5.66

*Note. Exp. = experimental group; df = degrees of freedom; * significant at α = 0.05. Effect size: conventional large threshold > 0.8 (Cohen, 1988); values > 2.0 are described as huge following Sawilowsky (2009). 95% CIs were calculated from the reported between-group mean differences and t statistics with df = 38.*

DISCUSSION

Wobble board training alone produced a significant, large-effect improvement in dynamic balance and a smaller but significant gain in explosive power. This balance gain is consistent with proprioceptive adaptation driven by repeated activation of mechanoreceptors at the ankle, knee, and hip, strengthening both anticipatory and corrective postural control. Such an effect aligns with evidence that instability-based wobble board training improves balance and proprioception in adolescents and in athletes with ankle instability (Emery et al., 2005; Taghavi Asl et al., 2022). The comparatively modest jump gain in the control group suggests that instability training alone provides limited plyometric stimulus for increasing jump height, since it emphasises postural control rather than the rapid, high-force stretch-shortening actions that most directly drive power adaptation (Malisoux et al., 2006).

The experimental group's larger gains reflect the complementary demands of single leg hop training. Each hop-and-land cycle on a single limb requires the neuromuscular system to manage high ground-reaction forces while maintaining postural control over a narrow base of support, a more complex challenge than wobble board stance alone. For explosive power, the improvement is consistent with the stretch-shortening cycle mechanism, in which rapid eccentric loading is followed immediately by a powerful concentric contraction; training based on maximal-effort stretch-shortening cycle exercise enhances lower-limb power output and jump performance (Malisoux et al., 2006). This is consistent with meta-analytic evidence that plyometric jump training improves jumping performance and related fitness attributes in basketball players regardless of age and sex (Ramirez-Campillo et al., 2022), with early pubertal male basketball players (Zribi et al., 2014), and with reports that combined balance and plyometric training improves athletic performance in adolescent basketball players (Bouteraa et al., 2020).

The adolescent stage of the participants may itself have contributed to the magnitude of the adaptations. Early adolescence is characterised by continuing development of motor coordination and neuromuscular control, and is widely regarded as a favourable window in which structured training can produce meaningful gains in balance and muscular fitness (Lloyd et al., 2014; Granacher & Behm, 2023). Because the participants were early adolescents, part of the early improvement may reflect neural adaptation and responsiveness to a structured training stimulus rather than structural muscular change alone. Moreover, because participants were grouped by chronological rather than biological age, individual differences in maturation may have influenced the response to training and contributed to variability in the gains (Malina et al., 2015). The gains reported here are therefore best interpreted as short-term training responses in a developing population rather than fully consolidated adaptations, reinforcing the need for follow-up measurement.

The greater improvement observed in the combined group may be explained by the complementary demands of the two training modalities. Wobble board training may have provided a foundation for postural control, while single leg hop training added a high-velocity unilateral loading stimulus that draws on the stretch-shortening cycle. Joint stability developed through wobble board work may create favourable conditions for force expression during single leg hop, and the impulsive loading of single leg hop may in turn reinforce the proprioceptive demands introduced by the balance task. However, because the study did not include a plyometric-only group, this interpretation should be regarded as a plausible explanation rather than evidence of a specific interaction between the two modalities; the observed between-group difference cannot be attributed unambiguously to an interaction between the two modalities. The present findings are consistent with literature suggesting that combined balance and plyometric approaches can improve physical qualities in youth athletes, but they do not establish that one within-session sequence is universally superior (Granacher & Behm, 2023; Bouteraa et al., 2020). It should be emphasised that the present study measured dynamic balance and vertical jump performance only, and did not directly measure injury incidence; any injury-prevention implication is therefore indirect, inferred from the established association between reduced dynamic neuromuscular control and increased lower-extremity injury risk (Plisky et al., 2006; Butler et al., 2013), and should be interpreted with caution.

These findings have several practical implications for coaches, physiotherapists, and physical educators working with adolescent basketball players. First, the results indicate that a relatively short, six-week program requiring only simple equipment—a wobble board and space for hopping drills—can produce measurable gains in two performance-related qualities at once, which is valuable in youth settings where training time and equipment budgets are often limited. Second, the sequencing used here, in which single leg hop preceded wobble board work within each session, allowed the more demanding explosive drills to be performed while athletes were less fatigued, and this ordering may help preserve movement quality during unilateral landing. Third, because the participants were early adolescents, the program should be introduced with an emphasis on correct technique before progressing volume and intensity, and under supervision, given that unilateral plyometric loading places high demands on a still-developing musculoskeletal system. Practitioners adopting this approach should therefore individualise progression to each athlete's competence and maturation rather than applying a fixed load to all players.

Limitations of the study

This study has several limitations, some of which concern its design. First, the control group performed only wobble board training and did not include any jumping stimulus; consequently, the between-group comparison for explosive power partly reflects the presence versus absence of a plyometric stimulus rather than an isolated effect of the single leg hop component alone, and this should be borne in mind when interpreting the power results. The control condition was therefore an active wobble-board condition, but it did not provide a comparable jumping stimulus or an alternative condition matched for the specific plyometric exposure. A design incorporating an additional group performing plyometric work without instability training, or a comparator receiving routine basketball training without the study-specific balance or plyometric intervention, would allow the specific contribution of each component to be separated more cleanly. Second, participants could not be blinded to group allocation because the exercise content differed visibly between the programmes; this may have contributed to expectation or performance effects and should be considered when interpreting the magnitude of the observed between-group effects. Third, the outcomes were limited to a general dynamic-balance test and a vertical jump test; sport-specific coordination and agility tasks (for example, reactive change-of-direction or basketball-specific movement tests) were not included, which would have permitted a more detailed analysis of transfer to basketball performance. Fourth, as a field-based study, environmental variables could not be controlled as tightly as in a laboratory, and out-of-program activity was self-reported. Fifth, biological maturation was not verified with objective markers, no follow-up measurement was taken, and the study was limited to a single club with a modest sample size, which constrains generalisability and statistical power for subgroup analysis. Finally, the comparatively large effect sizes should be interpreted with caution. Their magnitude may partly reflect the modest sample, single-site setting, responsiveness to a structured training stimulus during early adolescence, and the absence of a comparable jumping stimulus in the control condition; however, these are plausible contextual contributors rather than established causes. Future research should address these issues by adding appropriate active-control and plyometric-only groups, incorporating sport-specific coordination measures, objectively assessing maturation and out-of-program activity, and using larger, multi-site samples with follow-up assessment.

In addition, the trial was not prospectively registered in a publicly accessible clinical trial registry. Consequently, there is no prospectively registered record against which the prespecified outcomes and analyses can be independently verified. This limits transparency regarding prespecification and should be considered when interpreting the findings. Future randomized controlled trials should be prospectively registered before participant enrolment.

The between-group analysis was based on change scores rather than a baseline-adjusted ANCOVA model. Future studies may consider baseline-adjusted analyses to provide more precise estimates of treatment effects, particularly when baseline differences are present.

CONCLUSION

Six weeks of wobble board training improved dynamic balance and lower-limb explosive power in 13–14-year-old basketball players, while the addition of single leg hop training produced significantly greater improvements in both outcomes. However, because the control group did not receive a comparable plyometric stimulus, this study cannot determine the independent contribution of single leg hop training to the observed gains; the greater improvement in the experimental group may partly reflect the addition of a plyometric stimulus rather than the single leg hop component specifically. Because the study measured balance and jump performance rather than injury incidence, its findings support the use of combined wobble board and single leg hop training primarily to enhance these physical qualities in youth basketball athletes; any injury-prevention benefit remains to be confirmed by studies that measure injury outcomes directly.

On the basis of these findings, practitioners are encouraged to integrate combined wobble board and single leg hop training into structured youth conditioning, prioritising technique before progression and adjusting load to each athlete's competence and maturation. Future studies should verify biological maturation status, add an active-control and a plyometric-only comparison group, include sport-specific coordination and agility measures, and incorporate follow-up assessment to determine how long the observed adaptations are retained and whether they translate into reduced injury risk.

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AI DISCLOSURE STATEMENT

During the preparation of this manuscript, the authors used AI-based assistants, namely Claude (Anthropic) and ChatGPT (OpenAI), for language editing of the English text, assistance with reference formatting in APA style, and support for initial literature searching. The AI tools were not used to generate original research data, to perform or replace the statistical analysis, or to produce substantive scholarly content or conclusions. All AI-assisted outputs, including all cited references, were critically reviewed, verified against original sources, and thoroughly edited by the authors to ensure factual accuracy, originality, absence of plagiarism, and compliance with academic standards. The authors take full responsibility for the integrity and content of the manuscript.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to participant privacy and confidentiality considerations.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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