ENHANCING TEAMGYM PERFORMANCE WITH POWER TRAINING

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Abstract
Previous studies have highlighted a strong relationship between mechanical lower limb muscle function and TeamGym performance, specifically in terms of difficulty scores in trampette and tumbling disciplines. To date, no intervention study has explored whether enhancing lower limb muscle function can translate to improved TeamGym performance. We recruited eleven national-level TeamGym athletes (four males, seven females) for a quasi-experimental intervention spanning six weeks. The regimen comprised strength training sessions thrice weekly, emphasizing power and maximum strength. Pre- and post-intervention assessments included countermovement jumps, drop jumps, leg press power, 20m sprints, jump and reach, as well as video analyses of trampoline and tumbling performances. In line with prior research, our study uncovers significant correlations between physical test outcomes and TeamGym performance. Notably, leg press power exhibited a robust association with trampoline performance ($r=0.95$, $p<0.001$), while drop jump results correlated strongly with tumbling performance ($r=0.72$, $p<0.05$). Post-training, only the intervention group displayed a statistically likely uptick in leg press power. Additionally, the intervention group saw an average increase of 0.15±0.2 points in difficulty, contrasting with the control group's negligible change (0.0±0.2).Given the limited sample size in this preliminary pilot study, the results warrant cautious interpretation. Nonetheless, they resonate with prior findings, suggesting that augmenting an athlete's mechanical lower limb muscle function through targeted strength and power training can beneficially influence national-level TeamGym performance.

Keywords: *TeamGym, Power, Training, Performance, Intervention.*

INTRODUCTION

Gymnastics encompasses a range of disciplines, including sports acrobatics, rhythmic sports gymnastics, and artistic gymnastics. TeamGym (TG) is a specific gymnastics discipline where athletes compete in trampoline, tumbling, and floor exercises. A team typically comprises between 6 and 12 athletes. Athletes' performances are judged based on difficulty level, style, and composition (De Pero et al., 2021). TG has been gaining popularity, with European Championships held biennially since 1993. Despite its growing appeal, research specifically focused on TG performance remains limited (De Pero et al., 2021; Hansen, Hvid, Aagaard, & Jensen, 2019).

Similar to other gymnastic disciplines, TeamGym performance heavily relies on the ability to execute movements rapidly (De Pero et al., 2021; Hansen et al., 2019). Among the three disciplines in TG, the trampoline and tumbling apparatus are most dependent on muscular function (Elbæk, 1993). To improve performance in the trampoline or tumbling, athletes can enhance either the style or difficulty level of their skills. The ability to execute high-level skills in these apparatuses depends on the time available in the air (Hansen et al., 2019). Consequently, increasing the time in the air requires elevating the vertical impulse (force x time) generated during the push-off phase (Jemni & Sands, 2017). Achieving such an increase in impulse can be influenced by various factors. Arguably, optimizing the technique to achieve the highest impulse, such as hitting the apparatus at an optimal angle, is one of the most crucial factors (Jemni & Sands, 2017). However, for well-trained athletes who have nearly perfect technique after years of training, other factors to enhance the impulse also become significant (De Pero et al., 2021; Elbæk, 1993; Hansen et al., 2019; Jemni & Sands, 2017).

The use of springs in TG apparatuses allows for the force and energy applied to the apparatus to be temporarily stored in the spring. This energy then acts back on the athletes, propelling them into the air (Jemni & Sands, 2017). This spring mechanism implies that the highest jump heights are achieved by applying the maximum forces the athlete can tolerate, while staying within the mechanical limits of the springs (Jemni & Sands, 2017). In TG, athletes utilize a 15m long run-up track to build momentum, calculated as velocity multiplied by mass (Jemni & Sands, 2017). Therefore, the muscular capacity to accelerate the body along the 15m run-up track, coupled with the leg muscles' ability to handle the forces from the accumulated momentum, is crucial for TG athletes (Hansen et al., 2019).

To the best of the author's knowledge, only one study has explored the influence of muscular capacities on TG performance. Hansen et al. (2019) examined the relationship between mechanical lower limb muscle function and performance among a group of TG athletes. Participants underwent a series of tasks to assess their muscular function and reported their maximal performance levels on the trampoline and tumbling apparatuses. As anticipated, significant associations were found between measures of mechanical lower limb muscle function and TG performance. However, given that the study was cross-sectional in nature, caution is warranted when drawing causal inferences from these findings. To further our understanding and expand on current knowledge, an experimental study targeting muscular capacity is highly warranted (Hansen et al., 2019).

The aim of the present study was therefore to investigate whether improving muscular power would increase performance in TeamGym. We hypothesized that i) TG performance would be associated with measures of physical function and ii) an increase in muscular function due to training would result in improved TG performance.

METHODS

The sample consisted of 11 TeamGym athletes (age: 17.6 ± 1.1 years, weight: 63.1 ± 11.5 kg, height: 168.4 ± 11.0 cm) competing at the national level (4 males, seven females). Two participants could not complete the study, one due to an injury during gymnastics training and the other due to a quarantine period in connection with COVID-19. Consequently, nine participants completed the post-tests. Finally, the intervention group consisted of four subjects (three girls and one boy), and the control group consisted of five subjects (three girls and two boys).

The intervention group followed a structured power training program (see Table 1) over six weeks, consisting of three sessions weekly.

Table 1:
Training program for the intervention group

	Exercise	Reps	Set	Pause	Load / comment
Session 1	One-legged box jump	4	3	3 min	Bodyweight
	Drop jump up to box	5	3	3 min	Bodyweight
	Sprint 20m	3	2	3 min	Max effort
	Sprint 15m + resistance	5	2	3 min	Pushing plyo-boxes
Session 2	Drop jump to broad jump	4	3	3 min	Bodyweight
	Loaded squat jumps	5	3	3 min	20 - 40kg max effort
	Sprint 20m	3	2	3 min	Max effort
	Jump rope, 1 foot	60s	2	3 min	Jump Rope
Session 3	Back squat	5	3	3 min	1-2 reps in reserve
	Split squat	4	3	3 min	1-2 reps in reserve
	Bulgarian split squat	5	3	3 min	1-2 reps in reserve
	Hip thrust	5	3	3 min	1-2 reps in reserve

The three sessions included different exercises that focused on plyometric and high load strength training of the lower extremities, commonly recommended to increase power and jumping ability in athletes (Bauer et al., 2019). When the training program was created, the sport's uniqueness was kept in mind, using exercises that strengthen and challenge the movements one performs on the trampoline and tumbling. The training sessions were implemented in connection with the weekly gymnastics sessions to ensure that all practitioners in the intervention group completed the interventions correctly. The practitioners were asked to make corrections and received good follow-up during the six weeks of the intervention. The athletes were familiar with earlier exercises, making it easier to complete the training program. The control group performed basic training as usual at the end of the gymnastics sessions. The sessions were of the same type as before the project started. In exercises such as push-ups, unloaded jump squats, and burpees, bodyweight-inspired sessions with no external loads were used. The intensity of the heavier exercises was regulated by utilizing reps in reserve, with rep ranges aligning with a relative intensity of 70% 1RM and above. The training in the two groups was thus different, with different focus during the six weeks the intervention lasted.

Vertical jumps were performed following a protocol where participants kept their hands on their hips to standardize the movement and focus the effort on lower body. The assessment comprised two sets, each consisting of three jumps, to ensure reliability and allow athletes to demonstrate their maximal jumping capability. The highest jump from these six attempts was recorded for analysis. Jump heights were precisely measured using a force plate (Muscle lab; Ergotest AS, Porsgrunn, Norway)

Drop jumps were executed with hands on the hips. The participant stepped down from a 29 cm high box and was instructed to jump as high as possible, with the slightest contact time on the force platform. Two series of three trials were conducted, with the best result recorded. Jump height and the reactive strength index (Jump height/contact time) were measured using a force plate (Muscle lab; Ergotest AS, Porsgrunn, Norway).

The seated leg press was conducted using a "Keiser A300 horizontal leg press dynamometer" (Keizer Sport, Fresno, CA). Power results were obtained from a 10-repetition test with incremental loads. In this test, participants performed ten repetitions, exerting maximum effort as the load increased. The seat position was individually adjusted to ensure the femur was vertical, aligning with a knee joint angle at 80 ° - 90 °. Participants were instructed to fully extend both legs with maximal effort in each repetition. For further details regarding the apparatus, see Lindberg, Eythorsdottir, et al., 2021.

20-meter sprints were timed using a gate system that measured the time from 0-30m with 5-meter intervals (Muscle lab; Ergotest AS, Porsgrunn, Norway). The timing initiation was registered by a photocell placed at the start line, aligned with the participant's front foot. For this study, the focus was on the time taken to cover the 0-20 meter distance, which served as the primary measure for further analysis. The subjects completed three trials with a 3-minute rest period between them. If there was improvement in the third trial, an additional attempt was allowed.

The Jump and Reach test involved participants using a self-selected run-up to jump off one foot and reach the highest point possible on the apparatus. Two series of three trials were completed, with the average of the two best trials recorded. The "Vertec Vertical Jump Tester" (JUMPUSA; Sunnyvale, CA 94089, USA) was used for this assessment.

Video analysis was conducted during regular gymnastics training. Athletes performed their best competition routines on both the trampoline and tumbling, with simultaneous filming taking place. Subsequently, videos were analyzed in a blinded fashion — the evaluator was unaware of whether the videos were recorded before or after the intervention. A qualified judge assessed each athlete based on the difficulty (degree of difficulty) and execution, adhering to current TeamGym regulations (Turnforbund, 2019). The difficulty level of the routine (D-score) was calculated by summing the scores for all elements, which starts at zero with no upper limit. Execution (E-grade) ranged from 0 to 10, with athletes beginning at 10 points and having points deducted (typically in tenths) based on their performance throughout the routine (Turnforbund, 2019).

The present study utilized a quasi-experimental design, marked by the deliberate manipulation of an independent variable (the structured power training program) without randomizing participants into intervention and control groups. This design was selected due to the practical constraints of working with a specialized, competitive athlete population. Logistical and ethical considerations made randomization unfeasible. While this approach enabled an investigation into the effects of the power training program on TeamGym performance, it also recognized the limitations stemming from the absence of random assignment.

The Pearson product-moment correlation coefficient (Pearson r) was employed to ascertain the relationships between the physical and TeamGym performance tests. These analyses pooled data from all subjects at the pre-test, rather than within individual groups, to offer a comprehensive overview of correlations across the entire sample. The Pearson's r coefficients were categorized as follows: 0.00–0.09 trivial; 0.10–0.29 small; 0.30–0.49 moderate; 0.50–0.69 large; 0.70–0.89 very large; 0.90–0.99 nearly perfect; 1.00 perfect, as previously defined (W. G. Hopkins, S. W. Marshall, A. M. Batterham, & J. Hanin, 2009).

Effects were assessed using non-clinical magnitude-based inferences (MBD), a method suitable for small samples (W. Hopkins, S. Marshall, A. Batterham, & J. J. M. S. i. S. E. Hanin, 2009). The magnitude of changes within and between sessions was evaluated by standardization (mean change/difference divided by baseline SD of all subjects). The resulting standardized effect was assessed using a modification of Cohen's (1992) scale: <0.2 trivial; 0.2–0.6 small; 0.6–1.2 moderate; >1.2 large (W. Hopkins et al., 2009).

To infer clinically meaningful effects in the studied population, effects were expressed as probabilities of harm or benefit relative to the smallest worthwhile change (0.2 of SD; W. Hopkins et al., 2009). A clear change within or difference between pre-post or groups indicated an effect almost certainly not harmful (<0.5% risk of harm) and potentially beneficial (>25% chance of benefit).

The effect was presented as the difference or change with the highest probability, qualitatively categorized as follows: 25–75% possibly; 75–95% likely; 95–99.5% very likely; >99.5% most likely (W. Hopkins et al., 2009). Descriptive data are reported as mean ± SD. All statistical analyses were conducted using a customized Microsoft Excel spreadsheet (W. Hopkins et al., 2009).

RESULTS

For all participants combined, a large to very large relationship was observed between the physical performance tests and TeamGym performance (D-score) on the trampoline (r: 0.72 to 0.95, $p<0.05$) and tumbling apparatus (r: 0.56 to 0.72, $p<0.05$). Weaker correlations were found between physical performance and TeamGym E-scores (r: 0.06 to 0.72) (Table 2).

Table 2:
Correlation table comparing TeamGym performance with physical performance

	Reach (cm)	Cmj (cm)	Drop-jump (RSI)	20m time (s)	20m speed (m/s)	Power (w/kg)
Tumbling - (D)	0.56#	0.71*	0.72*	-0.55#	0.55#	0.67*
Tumbling - (E)	-0.32	0.06	-0.10	0.08	-0.15	0.06
Trampette - (D)	0.72*	0.92***	0.45	-0.87***	0.88***	0.95***
Trampette - (E)	0.55#	0.53#	0.26	-0.63*	0.72*	0.61*
Difficulty – Average	0.65*	0.87***	0.62*	-0.77**	0.77**	0.87***

*D: Difficulty, E: Execution, cm: Centimeter, s: Seconds, m/s: meter per second, W/kg: watts/bodyweight. RSI: Reactive strength index, Reach: Jump and Reach test, Power: Leg press power, Cmj: counter movement jump, *** p<0.001 ** p<0.01 * p<0.05, # p<0.10. n=11 from the pre-test.*

Table 3: Pre and post values for both groups, for all measurements.

		Pre			Post			Change					Individual			Group-differences (Int-Con)		
Test:	Group (n=)	Mean	±	SD	Mean	±	SD	Δ	±	SD	ES	Non-clinical MBI	↓	-	↑	Mean	ES	Non-clinical MBI
Jump and Reach (cm)	Int (4)	279.9	±	17.5	280.8	±	17.4	0.87	±	0.6	0.04	Trivial (Most likely)	0	4	0	-3.1	-0.11	Trivial (likely)
	Kon (5)	273.2	±	38.1	277.2	±	37.2	4.00	±	4.2	0.16	Trivial (likely)	0	3	2			
Cmj (cm)	Int (4)	36.7	±	9.4	37.7	±	8.6	1.05	±	1.3	0.16	Trivial (possibly)	0	3	1	3.0	0.50	Small (likely ↑)
	Kon (5)	33.6	±	3.5	31.7	±	2.9	-1.90	±	3.1	-0.29	Small (possibly ↓)	2	3	0			
Drop jump (RSI)	Int (4)	203	±	36.5	193	±	45	-10.2	±	49	-0.26	Small (unclear)	2	0	2	-3.7	-0.09	Trivial (unclear)
	Kon (5)	172	±	52.9	165	±	20	-6.5	±	38	-0.17	Trivial (unclear)	2	1	2			
20 m time (s)	Int (4)	3.03	±	0.3	3.04	±	0.3	0.01	±	0.0	0.04	Trivial (likely)	1	2	1	0.05	0.23	Small (possibly ↑)
	Kon (5)	3.13	±	0.2	3.09	±	0.2	-0.04	±	0.1	-0.17	Trivial (possibly)	2	3	0			
20 m velocity (m/s)	Int (4)	7.8	±	1.0	7.8	±	1.0	0.03	±	0.1	0.04	Trivial (Very likely)	0	1	3	0.0	-0.05	Trivial (Very likely)
	Kon (5)	7.5	±	0.6	7.6	±	0.6	0.07	±	0.1	0.09	Trivial (Very likely)	1	0	4			
Leg press Power (w/kg)	Int (4)	18.8	±	4.6	19.7	±	4.8	0.95	±	0.9	0.29	Small (likely ↑)	0	1	3	0.6	0.19	Trivial (possibly)
	Kon (5)	16.3	±	2.3	16.7	±	2.8	0.38	±	1.0	0.11	Trivial (likely)	1	3	1			
Tumbling - (D))	Int (4)	1.3	±	0.6	1.4	±	0.6	0.06	±	0.0	0.15	Trivial (likely)	0	4	0	0.1	0.24	Small (possibly ↑)
	Kon (5)	0.7	±	0.2	0.7	±	0.2	-0.03	±	0.1	-0.07	Trivial (likely)	1	4	0			
Tumbling - (E)	Int (4)	9.4	±	0.3	9.1	±	0.7	-0.30	±	0.5	-0.41	Small (likely ↓)	2	2	0	-0.9	-1.12	Moderate (Very likely ↓)
	Kon (5)	8.3	±	1.2	9.0	±	0.4	0.63	±	1.1	0.86	Moderate (likely ↑)	0	3	2			
Trampette - (D)	Int (4)	1.2	±	0.7	1.5	±	1.0	0.23	±	0.3	0.47	Small (likely ↑)	0	2	2	0.2	0.48	Small (likely ↑)
	Kon (5)	0.8	±	0.3	0.8	±	0.3	0.02	±	0.2	0.04	Trivial (likely)	1	3	1			
Trampette - (E)	Int (4)	9.2	±	0.6	9.1	±	0.4	-0.14	±	0.5	-0.30	Small (unclear)	2	0	2	-0.2	-0.50	Small (unclear)
	Kon (5)	9.1	±	0.5	9.2	±	0.3	0.09	±	0.4	0.19	Trivial (unclear)	2	0	3			
Difficulty- Mean	Int (4)	1.3	±	0.7	1.4	±	0.8	0.14	±	0.2	0.32	Small (likely ↑)	0	3	1	0.1	0.37	Small (likely ↑)
	Kon (5)	0.8	±	0.2	0.8	±	0.2	0.00	±	0.1	-0.01	Trivial (likely)	1	3	1			

*Int: Intervention group, Con: Control-group, D: Difficulty, E:Execution, cm: Centimeter, s: Seconds, m/s: meter per second, W/kg: watts/bodyweight, RSI: Reactive strength index, SD: standard deviation, ES: Effect size, MBI: magnitude-based inferences, Qualitative interpretations follow the scale: for ES: <0.2, trivial ; 0.2–0.6, small ; 0.6–1.2, moderate ; >1.2, large . Effects follow the scale: 25–75%, possibly; 75–95%, likely ; 95–99.5%, very likely; >99.5%, most likely. Individual changes are defined as >0.2*SD. ↓: Decrease / - no change / ↑ Increase*

Only the intervention group showed a statistically likely increase in leg press power following the training period (ES: 0.29 vs 0.11 for the control group). No other statistically likely improvements were observed in the other performance measures. The intervention group exhibited an average increase of 0.15±0.2 points in difficulty for trampette and tumbling (ES: 0.32 likely increase), whereas the control group showed no change (0.0±0.2) (Table 3).

DISCUSSION

The primary aim of this study was to investigate whether an improvement in muscular power would enhance performance in TeamGym. The results demonstrate a strong relationship between the physical performance tests and performance on the trampoline and tumbling apparatuses in TeamGym. Additionally, we observed a small but likely increase in both power and difficulty value on the trampoline of the intervention group. In contrast, the control group showed no tendency to increase either power or difficulty value across any apparatus. These findings confirm and build upon previous research, suggesting that higher physical performance benefits TeamGym outcomes and that targeted muscular power training can boost TeamGym performance.

Limited research exists on the relationship between muscular power development and TeamGym performance, as highlighted in the introduction. A study similar to ours was conducted by Hansen et al. in 2019. Consistent with our findings, they identified a correlation between TeamGym performance and leg extensor power, noting a strong relationship between sprint results and trampoline performance ($r = -0.87$; $p < 0.05$). This correlation is logical, as higher sprint speeds can lead to increased jump heights on the trampoline. Additionally, Hansen et al. found a robust link between Rate of Force Development (RFD) and trampoline performance. While we didn't measure RFD directly, its close association with muscular power (McGuigan, Winchester, & medicine, 2008) aligns with our strong relationship between muscular power and trampette performance. Our study also revealed some novel insights. Notably, drop jumps, which share biomechanical and neuromuscular similarities with tumbling, showed the strongest correlation with tumbling performance. The most significant finding, however, was that the strength and power training intervention group exhibited increases in both power and TeamGym performance, a change not observed in the control group.

Table 2 highlights a significant correlation between all physical tests and the TeamGym difficulty score. Leg press power showed the strongest association with trampoline performance ($r = 0.95$; $p < 0.001$), while the drop jump was most closely linked with tumbling ($r = 0.72$; $p < 0.05$). Figure 1, derived from Table 2, depicts the relationship between difficulty value in the trampoline and leg press power (W/kg). The regression line indicates that for every 1 W/kg increase in power, the difficulty value rises by 0.15 points.

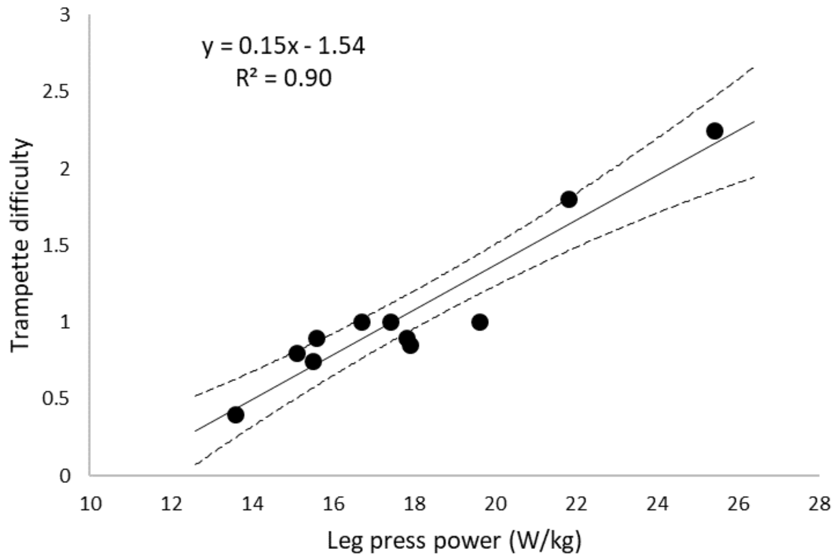

Figure 1: Correlation between trampette difficulty and leg press power. W/kg; Watts per kg bodyweight. n=11 from the pre-test.

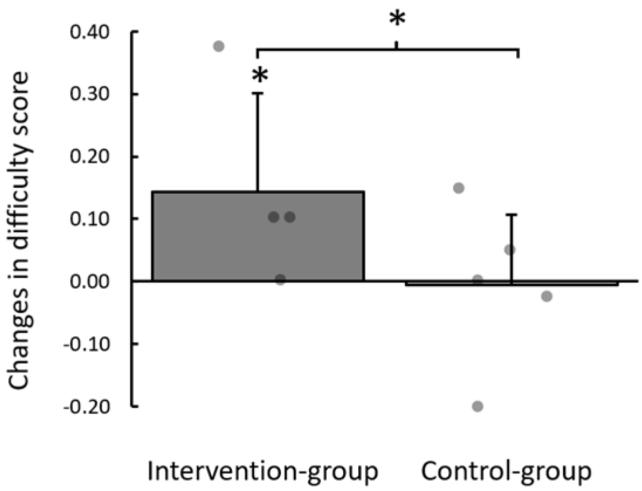

Figure 2: Changes in averaged difficulty level on trampette and tumbling apparatus. *Likely increase/ difference between groups.

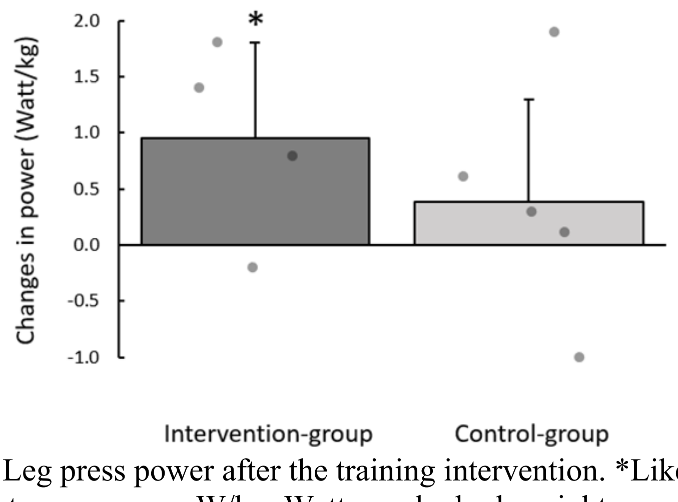

Figure 3: Changes in Leg press power after the training intervention. *Likely increase/difference between groups. W/kg; Watts per kg bodyweight

Interestingly, the intervention group saw an average increase of 0.15 points in difficulty value, whereas the control group showed no change (Figure 2). Figure 3 reveals that both groups experienced an increase in leg extensor power (W/kg), but only the intervention group's increase was statistically significant. These results suggest that enhancing muscular power can lead to an increase in the difficulty value in TeamGym performance.

The training intervention primarily impacted leg press power, while the other jump and sprint tests showed no significant changes. This limited effect, with an effect size of 0.29, could be attributed to the leg press test's higher measurement accuracy and better standardization (Lindberg et al., 2022; Lindberg, Solberg, et al., 2021). Given the predetermined positions and reduced technical variability in this test, results are less influenced by technique compared to more varied tests like drop jumps, fall jumps, and sprints (Lindberg et al., 2022; Lindberg, Solberg, et al., 2021).

The relatively short duration of the training intervention, spanning only 6 weeks, likely contributed to the modest effect size. Prior research with longer durations, ranging from 8 to 24 weeks, has reported effect sizes up to 0.8-1.0, whereas studies of approximately 6 weeks typically yield an average effect size of 0.42 (Bauer et al., 2019; Freitas, Martinez-Rodriguez, Calleja-González, & Alcaraz, 2017). Moreover, it's conceivable that the impact might have been more pronounced with athletes starting at a lower performance level than those in our study (Freitas et al., 2017).

Building on these findings and previous recommendations, it's advised that TeamGym athletes prioritize the development of muscular power, jump height, and sprint and acceleration capabilities. Hence, incorporating plyometric jump training along with heavy resistance exercises can establish a robust foundation of muscle strength and power, essential for mastering the specialized acrobatic skills integral to TeamGym performance.

CONCLUSION

This pilot study suggests that incorporating power training can yield positive effects on TG performance among national-level athletes. Given the limited number of participants in this study, it's essential to interpret the results with caution. However, aligning with the current findings and existing literature, we advocate for integrating power training into the foundational conditioning regimen for TeamGym athletes. Specifically, a blend of heavy-load and low-load plyometric exercises appears to be a potent approach for enhancing power and jump-related performance among national-level athletes, crucial for optimal TG outcomes. Future research endeavors should aim for larger sample sizes to achieve more broadly applicable and generalizable results.

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