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EFFECT OF 4-WEEKS COMPLEX TRAINING ON PHYSICAL PERFORMANCE AMONG RECREATIONAL MALE COLLEGIATE ATHLETES

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ABSTRACT

A growing body of literature shows a keen interest in complex training as an alternative training program to improve athletic performance. Inconsistent results remain mixed regarding its effectiveness, particularly in recreational male collegiate athletes. This study aims to evaluate the effects of 4-weeks complex training program on speed, agility, explosive power, and strength among recreational male collegiate athletes. A total of 48 participants (19.35 ± 1.51) from a public college volunteered, consented to participate and were randomly assigned between complex training group (CTG = 24) or control group (CG = 24). The participants underwent four physical tests assessing speed (30-meter sprint test), agility (Illinois Agility test), power (Countermovement jump test) and strength (1-RM Bench Press test). The findings revealed that CTG shows statistically significant improvements in all variables, ($p < 0.05$), while no significant changes detected in all variables for CG ($p > 0.05$). Both CTG and CG have shown significant Group × Time interaction in all variables ($p < 0.05$). The outcome of this study shows that 4-weeks of complex training intervention provide improvement on several physical performance among recreational male collegiate athletes. This suggests that complex training able to improve strength and power within one single training session.

Keywords: *Complex Training, Resistance Training, Plyometrics Training, Recreational Collegiate Athletes*

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INTRODUCTION

Designing and determining training is always challenging for athletes, coaches, trainers and even strength-conditioning professionals. In general, a typical resistance training program is designed to achieve strength gains alone usually required a higher intensity of training with lower training volume (Haff, 2015). However, a resistance training program primarily targets power required to focus more on work done over a unit of time. The fundamental objective of an effective resistance training program is to enhance both strength and power simultaneously within a single training session(Mcbride et al., 1999).

One training intervention that has gained attention for its potential to enhance these physical performance is known as complex training (CT), a method that alternates between high-load resistance training (RT) and plyometric training (PT) which are biomechanically similar within a single session (Cormier et al., 2020). CT has gained significant interest for its potential to integrate both strength and power development in a single training session, thereby maximizing neuromuscular adaptations and improving overall physical performance (Docherty et al., 2004; Hodgson et al., 2005). The theory of CT suggests that performing resistance exercise before plyometric exercise improves the effectiveness of plyometric activity, due to the increased motor neuron excitability triggered by the prior heavy load (May et al., 2010).

Recent studies have explored the effect of complex training on various performance fitness components in both novice and advanced athletes. For instance, a study by Gee et al. (2021) demonstrated an improvement in vertical jump performance among university-level athletes following a 6-week CT program. Similarly, Marshall et al., (2021) observed an increase in countermovement jump (CMJ) height in trained soccer players after an 8-week CT intervention. In addition to jump performance (power), CT also has shown promise in improving speed and agility. The combination of heavy resistance exercises with explosive plyometrics is thought to improve the rate of force development (RFD), a key determinant of sprint acceleration and agility (Suchomel et al., 2018). Research by Scott et al., (2023) showed improvement in sprint speed among university-level rugby players after an 8-week CT regimen. Another study by Thongnum & Phanpheng, (2022) reported significant gains in agility, with athletes completing agility tests faster after engaging in a CT intervention. This evidence proves that CT can improve several physical performances, making it a valuable addition to the training programs of sports that demand these qualities.

While the benefits of CT are supported by some evidence, empirical results remain mixed regarding its effectiveness, particularly among recreational male collegiate athletes(Brito et al., 2014; Stasinaki et al., 2015). Previous studies has proved that CT can lead to improvements in speed, agility, strength and power, but the optimal protocols and their effect on health- and skill-related fitness components are still debated (Biel et al., 2023). Thus, the primary aim of this study is to evaluate whether 4-weeks of complex training program can improve speed, agility, explosive power, and strength among recreational male collegiate athletes.

METHODOLOGY

Participants and settings

Forty-eight recreational male collegiate athletes (n = 48; aged = 19.35 ± 1.51) volunteered to participate in this study. A priori sample size calculation was performed using G*Power software (Version 3.1.9.7), and it was determined that a minimum number of 15 participants per group was required for this research. However, to account for potential dropout rate, the participants was increased to 24 participants per group (n = 48). This adjustment ensures the study retains sufficient power even if 20% of participants withdraw.

Participants were randomly assigned to two groups complex training group (CTG = 24) and control group (CG = 24) using the computer-generated randomization tool. This approach ensures that every eligible athlete has an equal chance of being selected, reducing selection bias and enhancing the external validity of the study. Participants were excluded if they suffered from an upper- or lower- limb injuries within three months before the intervention or if they had a current injury during the testing that prevented them from complete participation in this study.

The selected subjects were fully informed of the procedure of study and have given written informed consent. The current study was fully approved by the Research Ethics Committee (REC) of Universiti Teknologi MARA (UiTM) Shah Alam, Malaysia, REC/05/2025 (PG/FB/22).

Study Design
This study utilized a repeated-measures design to investigate the effects of 4-weeks complex training program on speed, agility, power and strength among recreational male collegiate athletes. Participants were evaluated at the start (before intervention) and the end of week 4 (after intervention). The tests were conducted on two consecutive days. Due to the possible of PAP influence by performing strength exercise prior to speed and jump tests,1-RM strength test was conducted as the final test session. The first day was to evaluate 30-m sprint and Illinois agility test (IAT). The second day was conducted to assess CMJ and 1-repetition maximum Bench Press test (1-RM BP). All testing and training sessions took place at the same venue and time to reduce circadian fluctuation under direct supervision of the researcher and several research assistants.

Testing

Speed (30-m sprint test)
Speed performance was recorded in a single linear maximum effort 30-m sprint using timing gates (Brower Timing System Speed Trap II) that were placed at the starting and finish lines. The timing gates were positioned at a height of approximately one meter to capture the chest of the athlete as they cross the beams. Each participant required to start the sprint from stationary position, so that the first movement could trigger the timing gate. The sprint continues for the full 30 meters, and the time stops when the athlete crosses the finish line. Each athlete performs two maximal-effort sprints, with a five-minute recovery period between trials to prevent fatigue from affecting performance. The fastest time of the two attempts was recorded for further analysis.

Agility (Illinois agility test)
The Illinois Agility Test (IAT) consisted of maximal sprinting and changing direction capabilities within a 9.2 × 7.2-m area, which has previously described from past study. The IAT was recorded using timing gates (Brower Timing System Speed Trap II) to ensure accurate and reliable measurement. The timing gates were placed at the starting and finish lines. Participants required to sprint 10 meters straight, turn around the cone, return to the start line, weaves in and out of the middle cones, and then complete another 10-meter sprint to the finish line. Two trials are conducted with a five-minute recovery period between attempts, and the fastest time was recorded.

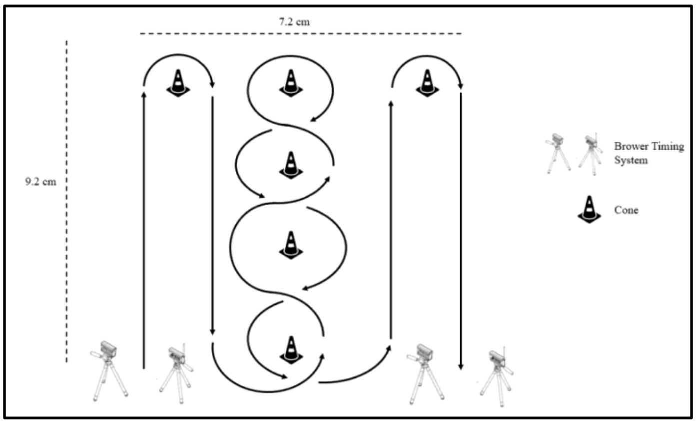


Figure 1: The Illinois Agility test course

Power (Countermovement jump test)
The countermovement jump test (CMJ) was commonly used assessment to evaluate lower limb explosive power, measuring the maximum vertical jump height of participants. This test was conducted using the MyJump2 App (v.5.0.9) on an iPhone 11 (Apple Inc., Cupertino, CA, USA). Every participant started in standing position with both hands at their waist. Then, participant executed the jump by consecutively flexing and powerfully extending the knees. The jump height was evaluated between two frames by selected trained rater, specifically take-off (first frame in which both feet left the ground) and landing phases (second frame in which one of the feet touched the ground). Three attempts were allowed, with approximately 30 seconds of resting period between trials and the best jump height was recorded. The jump was recorded by the rater which set-up the iPhone 11 facing the participant (in frontal plane), approximately 1 meter above the ground level and 1.5 meters away from the participant focusing on the participants' feet.

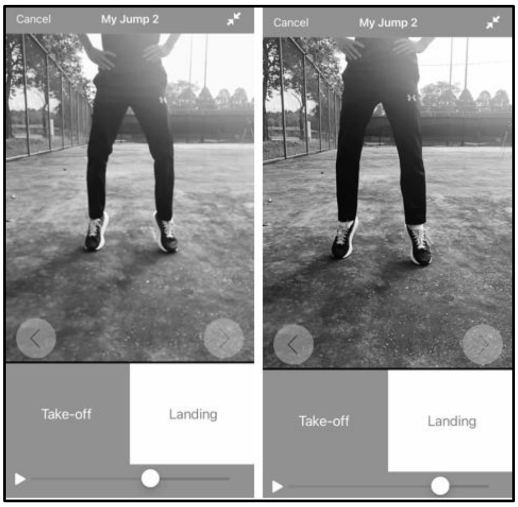


Figure 2: Difference in pretest and posttest power (CMJ test) using MyJump2 App

Strength (1-RM bench press test)
The 1RM (one-repetition maximum) bench press test is a gold standard for assessing upper-body maximal strength. The test was carried out using an Olympic 20-kg barbell, weight plates, two safety locks and bench racks, with two spotters positioned on the sides of the bar assisting the participant and one recorder. This study was adopted from strength test procedure based on a progressive increase in load with 3-5 minutes rest interval between each attempt. Participants performed one repetition at progressively heavier weights until their maximum capacity was reached. Every participant was given three attempts for this test. To prevent injuries, the final load lifted must be within the range of 3-5 reps and entered in a generic equation of 1-RM estimation.

Training Intervention
This study aims to develop muscle strength and explosive power through CT intervention which is suitable for recreational male collegiate athletes. The CT program have implemented 3 sessions weekly for 4 weeks, with each session lasting approximately 60 minutes. Every session includes 4 paired exercises of CT, with each pair consists of RT exercise followed by PT exercise targeting the same muscle groups. This study uses 3 sets of 4-5 repetitions and 75-85% of 1RM which are beneficial for improving strength and explosive power. CT intervention is grounded based on previous studies that demonstrated effectiveness of CT in improving speed, agility, power, and strength. To ensure participants get adequate rest period, intervention sessions were not scheduled on consecutive days. Participants data of pre- and post-test were included in statistical analysis if the attendance of participants achieved rating of ≥80% for intervention sessions.

Table 1: shows Complex Training Intervention

Week	Resistance Exercise	Sets × Reps	Intensity (%)	Plyometric Exercise	Sets × Reps
1-2	Back Squat	3 × 6	75	Box Jumps (20 cm)	3 × 6
	Bench Press	3 × 6		Plyometric Push-ups	3 × 6
	Deadlift	3 × 6		Horizontal drop jumps	3 × 6
	Overhead Press	3 × 6		Overhead Medicine Ball Throws (2 kg)	3 × 6
3-4	Back Squat	3 × 5	80	Box Jumps (30 cm)	3 × 6
	Bench Press	3 × 5		Plyometric Push-ups	3 × 6
	Deadlift	3 × 5		Horizontal drop jumps	3 × 6
	Overhead Press	3 × 5		Overhead Medicine Ball Throws (5 kg)	3 × 6

Data Analysis

Independent t-test was used to compare the pretest between CTG and CG to assess the baseline assumption. A 2 (group: complex training, control) × 2 (time: pre-test, post-test) repeated measures ANOVA was conducted using IBM SPSS Statistics (Version 29.0, IBM Corp, Armonk, NY, USA). A priori power was utilized with a power of 0.80 and an alpha level of 0.05. The normality of the data was assessed using Shapiro-Wilk, and all variables were confirmed to be acceptable. Equality of variances were assessed using Mauchly's Test of Sphericity. An epsilon value of < 0.75 will warrant the Greenhouse – Geisser correction while epsilon values of > 0.75 will warrant the Huynh – Feldt correction as elaborated by Girden (1992) (Blanca et al., 2023). Post hoc testing was conducted using Bonferroni to reduce the likelihood of Type 1 errors.

RESULT

Table 2: Baseline testing for CTG and CG using Independent T-test.

	CTG (Mean ± SD)	CG (Mean ± SD)	*p*-value
Age (yrs.)	19.25 ± 1.539	19.46 ± 1.503	.637
Height (cm)	170.21 ± 3.753	171.71 ± 5.575	.281
Weight (cm)	62.83 12.593	65.79 ± 12.511	.418
30M Pre (s)	4.89 ± .385	4.918 ± .45	.818
IAT Pre (s)	17.714 ± 1.482	17.446 ± 1.249	.501
CMJ Pre (cm)	34.49 5.23	35.59 ± 4.18	.427
1-RM BP Pre (kg)	41.18 ± 8.97	43.95 ± 11.05	.345

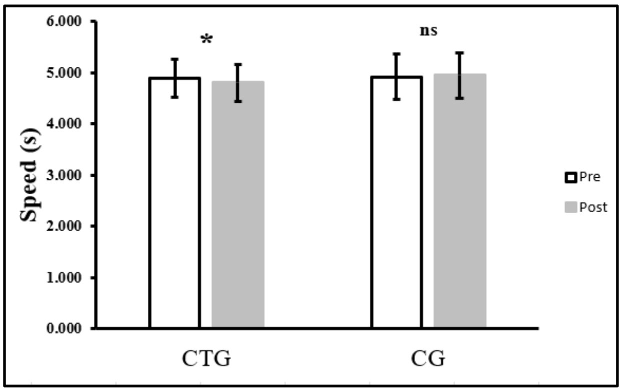
30-m sprint = 30-meter Sprint test; IAT = Illinois Agility test; CMJ = Countermovement Jump test; 1-RM BP = One-Repetition Maximum Bench Press test; SD = standard deviation; yrs. = years; s = seconds; cm = centimeter; kg = kilogram.

All participants completed both pre- and post-tests (n = 48). CTG has shown statistically significant improvements in all variables, 30-m sprint (4.89 ± 0.38, 4.8 ± 0.36, p = <0.001), IAT (p = 0.004), CMJ (p = <0.001) and 1-RM BP (p = <0.001) whereas no significant changes were observed in all variables for CG (p > 0.05). Also, CTG and CG have shown significant Group × Time interaction in all variables (p < 0.05). Table 4 shows a detailed analysis of repeated measures ANOVA in physical performance tests for CTG and CG.

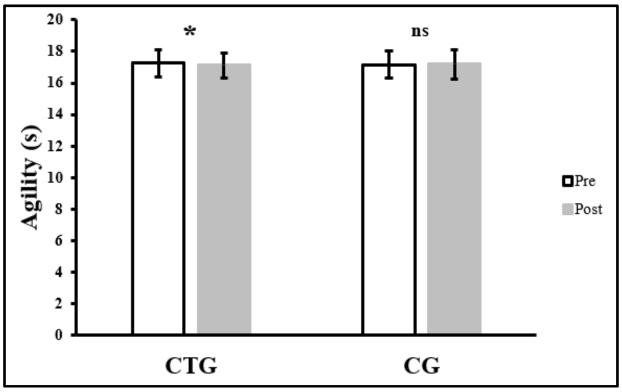
Table 3: Repeated measures ANOVA and post-hoc for Speed, Agility, Countermovement Jump and 1-RM Bench Press tests

Variables	CTG		*p*-value	CG		*p*-value	ANOVA	
	Pre	Post		Pre	Post		Time	Group × Time
Speed	4.89 ± 0.38	4.8 ± 0.36	<0.001	4.92 ± 0.45	4.95 ± 0.44	0.171	0.081	<0.001
Agility	17.71 ± 1.48	17.57 ± 1.44	0.004	17.45 ±1.25	17.47 ± 1.28	0.595	0.084	0.015
CMJ	34.49 ± 5.23	36.67 ± 5.27	<0.001	35.59 ± 4.18	35.19 ± 4.2	0.102	<0.001	<0.001
Bench Press	41.18 ± 8.97	43.46 ± 8.78	<0.001	43.95 ± 11.05	43.08 ± 10.8	0.107	0.014	<0.001

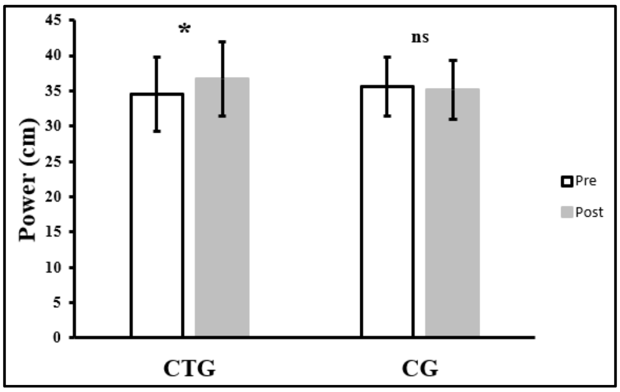
CTG = Complex training group; CG = Control group; 30-m Sprint = 30-meter Sprint test; IAT = Illinois Agility test; CMJ = Countermovement Jump test; 1-RM BP = One-Repetition Maximum Bench Press test; s = seconds; cm = centimeter; kg = kilogram.



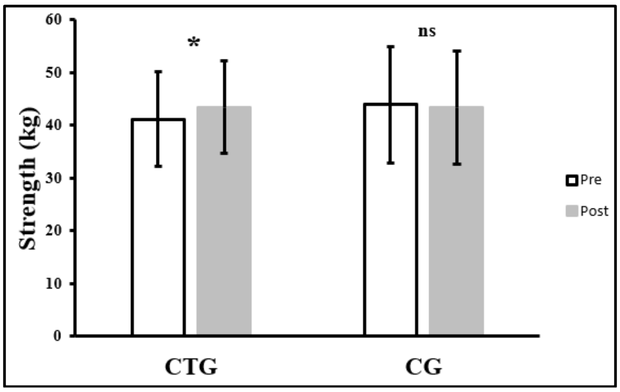
Graph 1: Difference in pretest and posttest speed (30-meter Sprint test) in both groups. (**ns**) no significant. (*) indicates significant difference compared to pretest value.



Graph 2: Difference in pretest and posttest agility (Illinois agility test) in both groups. (**ns**) no significant. (*) indicates significant difference compared to pretest value.



Graph 3: Difference in pretest and posttest power (Countermovement jump test) in both groups. (**ns**) no significant. (*****) indicates significant difference compared to pretest value.



Graph 4: Difference in pretest and posttest strength (1-RM bench press test) in both groups. (**ns**) no significant. (*****) indicates significant difference compared to pretest value.

DISCUSSION

This The current study purposed was to investigate the short-term (4 weeks) effects of CT on several physical performance components among recreational male collegiate athletes. CTG appears to show statistically superior improvements in speed, agility, power and strength among male collegiate athletes. The results of this study indicated that add values to some of previous research which indicates an improvement in athletic performance after performing complex training intervention (Ali et al., 2019; Kyung & Park, 2024).

CTG indicates significant improvement in speed performance (30-m sprint) compared to the CG. Since CG did not show any significant improvement in speed performance, it can be inferred that speed performance gains observed in the CTG were a direct result of CT intervention. According to Zhai & Qin (2024), maximal strength can heavily influenced speed performance, the CT intervention in this study incorporates high-intensity resistance training which may have an effect on 30-meter sprint. The study by Torres-Torrelo et al., (2018) examined the effects of 6-weeks of CT showing significant improvement in 30-meter sprint performance and countermovement jump with no significant changes observed in control group among futsal. Another previous study also found an improvement in 20-m sprint performance after 6-weeks of CT intervention among university soccer players (Ali et al., 2018). The result of this study show an enhancement in explosive force, movement and power, which implies neurologic adaptations to the training interventions (Comfort et al., 2014), and this adaptation causes improvement in 30-meter sprint as supported by previous studies (Alves et al., 2010; García-Pinillos et al., 2014; Kotzamanidis et al., 2005; Talpey et al., 2016). In addition, another explanation that can influenced the increase of 30-meter sprint is the “PAP theory” concept, according to which the use of heavy load exercise is needed to activate all motor units recruitments and therefore promotes in achieving highest neuromuscular activation (Ali et al., 2018).

Agility has been acknowledged as one of the key components for the overall success in sports (Sekulic et al., 2019). The present study indicates an improvement in the agility performance of CTG compared to the CG. A study by Shahidi et al., (2021) showed that 4-weeks of CT gives positive impact on agility performance among elite badminton players. In addition, Thongnum & Phanpheng (2022), also stated that 6-weeks of CT integrated with skill training significantly improve agility performance among amateur male soccer players. However, other studies have yielded contradictory results when evaluating complex training on agility performance. A study by Alves et al (2010) found no improvement in 505 Agility test after 6-weeks of CT among male soccer players (17.4 years). Another study by Krzysztofik et al., (2025) also stated that there was no significant changes in agility performance after 6-weeks of CT intervention among youth soccer players. These differences in previous studies might be due to the details of the training program (intensity and duration), population age (young, adolescent and adult), type of population (amateur, elite and professional) and the chosen test (number of changes of direction and angle of changes direction) (Alves et al., 2010; Hammami et al., 2017; Keiner et al., 2014). Another plausible explanation is due to the PAP effect by combination of resistance and plyometric exercises in the same training session (Ebben, 2002; Sanchez-Sanchez et al., 2021). However, this study indicated that short-term (4 weeks) effects of CT appear to show significant improvement in agility (IAT) performance among recreational male collegiate athletes.

Jump performance (CMJ) has been commonly used to assess lower-limb power output (Philpott et al., 2021). The result of this study suggests that combination of resistance and plyometrics training within the same training session can increase performance in CMJ. This finding parallels with Berriel (2022), who stated that 4-weeks complex training consisting of a set of resistance exercises followed by plyometric exercises can induce significant improvement in countermovement jump among male professional athletes. Similarly, (Kyung & Park, 2024) also reported 6-weeks of complex training can significantly improve CMJ. This suggests that a plausible explanation for improvement in jump performance could be that complex training stimulates neuromuscular system, which activates both muscular fibers and nervous system, so that slow-twitch muscle fibers act like fast-twitch muscle fibers (Alemdaroğlu et al., 2013; Qiao et al., 2022). This also proves that CMJ reflects lower-limb power, which is connected with strength and speed performance (Jadczak et al., 2019). Apart from that, several different factors such as coordination levels, body segments synchronization and muscular strength/force might have beneficial effects that should be emphasized (Suchomel et al., 2016).

Maximal strength also has been recognized to be important based on its association with other physical performance components (Suchomel et al., 2016). In the present study, CTG showed improvement in 1-RM BP which also supported by other studies with adolescent (Christou et al., 2006) and collegiate soccer players (Brito et al., 2014; Miranda et al., 2022). These results are not surprising because combination of resistance training and/or explosive power exercises provides an effective neural stimulus, which enhances recruitment of motor units, frequency coding (rate of action potentiation), synchronization and intermuscular coordination which all positively affecting force-time characteristics (e.g. rate of force development and absolute force) (Miranda et al., 2022; Suchomel et al., 2016). In other words, it increases muscle growth when performing resistance training and ultimately improves muscle strength performance. Another reasonable explanation for these result could be due to the participants already had little experience in strength training (Juárez et al., 2009).

Despite the valuable insights gained from the study, it is important to note some limitations. The period of intervention was relatively short (4 weeks), which may not capture the long-term effects. The study also limited to a small sample size 48 recreational male participants are still considered small sample size which raise concerns about effects of practice or potential placebo. Therefore, future studies must address these factors in order to provide a more accurate interpretation of results and better understanding of the possible implications for athletic performance results.

The findings of this study provide practical implications for athletes and coaches. First, complex training able to provide insight for coaches and trainers whether to include complex training program as one of the interventions in training regimen. For athletes, it can lead to better on-field performance, such as faster sprints, quicker directional changes, higher jumps and total upper body strength. By understanding the benefits of complex training, athletes can optimize their training regimen to maximize their explosive power and overall athletic capability. For players who have plateaued with traditional training methods, complex training may offer a new avenue for breaking through performance barriers and gaining a competitive edge.

CONCLUSION

The current study indicates that 4-weeks of complex training can improve several physical performances among recreational male collegiate athletes. Complex training group has shown improvement across all physical performance tests assessing speed, agility, power and strength. These findings contribute to the expanding of academic discourse, especially on complex training intervention by incorporating university population from intermittent sports.

AUTHORS' CONTRIBUTION

Wan Muhammad Afiq Wan Jahari was responsible for writing up the manuscript. Norlaila Azura Kosni was responsible for reviewing data analysis and results section. Muhammad Hamdan and Raja Mohammed Firhad Raja Azidin were responsible for reviewing discussion and conclusion section. Nurul Diyana Sanuddin was responsible for reviewing introduction section. Rabiu Muazu Musa was responsible for reviewing methodology section. All authors have contributed to the conception and design of the study. Material preparation, data collection and analysis were performed by the first author and guided by the other authors. The final manuscript has been reviewed and approved by all the authors.

CONFLICT OF INTEREST

There was no conflict of interest to be reported.

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