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RESEARCH

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Partial versus full range of motion triceps strength training on shooting accuracy among recreational basketball players: a randomized controlled trial

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Abstract

Background The benefits of strength training on shooting accuracy in football players and other athletes are well known, but its effectiveness in improving shooting accuracy among basketball players remains unclear. Therefore, this study aimed to determine the effect of partial range of motion (PROM) and full range of motion (FROM) triceps strength training on stationary three-point shooting test (S3P) among recreational basketball players.

Methods This was a single-blinded randomized controlled trial. 30 participants were randomly assigned into 3 equal groups; FROM, PROM, and control (CON). Triceps strength training was carried out using an adjustable overhead cable crossover machine. With shoulders over-head flexed to 160–180° for both experimental groups, the FROM group performed strength training from full elbow flexion to full extension. In contrast, the PROM group worked at a restricted range, between 60°-110° elbow flexion/extension. Both groups engaged in 4 sets of 10 repetitions, 2 sessions/week for 4-weeks at 67% of 1 repetition maximum, while the CON group did not participate in any exercise program. S3P was assessed at baseline and at the end of 4-weeks intervention.

Results Participants mean age (20.20 ± 1.54 years), height (1.74 ± 0.61 m), and body mass index (22.55 ± 3.31) were descriptively analysed. Within group analysis showed a significant improvement of S3P in both FROM ($p = 0.0345$, *95% CI* = -1.50 to -0.07, *ES* = 0.81) and PROM ($p = 0.005$, *95% CI* = -2.44 to -0.97, *ES* = 2.40) compared to CON group ($p = 0.8995$, *95% CI* = -0.61 to 0.68, *ES* = 0.05). Group-by-time interaction demonstrated PROM to be more promising ($p = 0.0102$, *95% CI* = -1.70 to 0.21) than the FROM and CON groups.

Conclusions PROM triceps strength training improves shooting accuracy and is a time-efficient technique highly recommended for basketball players.

Trial registration clinicaltrials.gov, NCT04128826, registered on 14/10/2019 - retrospectively, https://clinicaltrials.gov/study/NCT04128826.

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Keywords Basketball players, Full range of motion, Partial range of motion, Stationary three-point shooting test (S3P), Shooting accuracy, Triceps strength training

Background

Optimally tailored weight training programs are designed on certain scientific principles. These principles aim to modulate essential training variables such as the exercise order, frequency, volume, intensity, duration, rest intervals between sets, etc [1, 2]. The specific adaptations to imposed demands (SAID) principle implies that training effects are specific to the recruited muscle groups and the type of training protocol implemented [3]. Resistance training (RT) combined with range of motion (ROM) plays a crucial role in determining the effectiveness of training outcomes [4]. It has been widely anticipated that full range of motion (FROM) strength training is associated with increased muscle hypertrophy and strength compared to partial range of motion (PROM) training [5, 6].

FROM being the traditional mode of training is frequently promoted and advocated over PROM, even though both training methods have been reported to show improved strength outcomes [7]. FROM is expected to induce a higher amount of mechanical stress equally throughout the length of the muscle, and this may be a reason why most researchers prefer FROM training mode [5, 8]. In fact, it has been proposed that PROM may negatively affect joint flexibility as opposed to traditional FROM [9]. Nonetheless, few studies have proven that PROM training has multiple benefits, ranging from rehabilitative protocols to improving muscle strength and hypertrophy [2, 10, 11]. In addition, some studies have demonstrated that PROM increases isometric strength within the specific trained ROM and throughout the FROM [10, 12].

In RT, ROM training is considered most beneficial and effective if the repetition is halted right before achieving a full contraction since this prevents the load from being constantly applied to the working muscle [13]. For some exercises, the risk of a muscle tear is increased by the point of total contraction on the negative movement as muscle fibers are stretched way beyond the control point [14, 15]. Shooting a basketball involves precise coordination of the shoulder, elbow, and wrist joints, often within a controlled ROM. A good ROM in these joints facilitate proper alignment, fluidity, and consistency in the shooting motion [16]. While effective rebounding requires hip and knee flexion during the crouch phase and rapid extension to elevate off the ground, a FROM in these joints enhances the player's jump height and efficiency [17]. Lateral movements, pivots, and rapid direction changes depend on adequate hip, knee, and ankle ROM, which ensures the athlete's agility and speed [18]. Proficient athletes tend to exhibit better autonomous upper limb joint movements and a limited ROM or flexibility, particularly in the shoulders can hinder proper shooting mechanics. Therefore, ROM is a critical factor for basketball athletes, influencing not only technical performance but also physical resilience [19]. When shoulder is elevated beyond 90°, the medial head of the triceps is activated [20]. Thus, it can be implied that during basketball shooting, the medial head of the triceps is most important as the shoulder elevation is more than 90°. Based on the analysis of muscle force and activation of each head of the triceps concerning ROM of shoulder and elbow joints, the medial head of the triceps is highly activated at 180° of shoulder elevation and 60°-110° of elbow flexion/extension [20].

We hypothesize that strengthening the triceps in this particular ROM with shoulders elevated to 160–180° and performing elbow flexion/extension within a restricted range, between 60°-110° may significantly improve the basketball shooting accuracy. In addition, current research is scarce regarding the efficacy of FROM and PROM on shooting accuracy in basketball players. Besides, the effect of ROM training on outcomes related to the upper limbs is still lacking [6]. Therefore, this study aimed to compare the effect of triceps FROM and PROM strength training on stationary three-point shooting test (S3P) in recreational basketball players.

Methods

Study design and recruitment

This single-blinded (researchers measuring outcome variables were blinded) randomized controlled trial was carried out in the Physiotherapy Centre, M Kandiah Faculty of Medicine and Health Sciences, at Universiti Tunku Abdul Rahman (UTAR), Sungai Long, Malaysia, and strictly adhered to the Consolidated Standards of Reporting Trials (CONSORT) guidelines. The study was designed, executed, and reported following the CONSORT 2010 statement to ensure the transparency and completeness of trial reporting (Fig. 1). The sample size was determined through power analysis, using a repeated measures ANOVA (within-between interaction) with an effect size of 0.4, a significance level of $p < 0.05$, and a study power of 95%. Based on these parameters, the required sample size was calculated to be 30 participants. The effect size of 0.4 was derived from a previous study that investigated the impact of resistance training on shooting accuracy among young basketball players [21]. The participants of interest were UTAR undergraduate students and were reached through posters, University

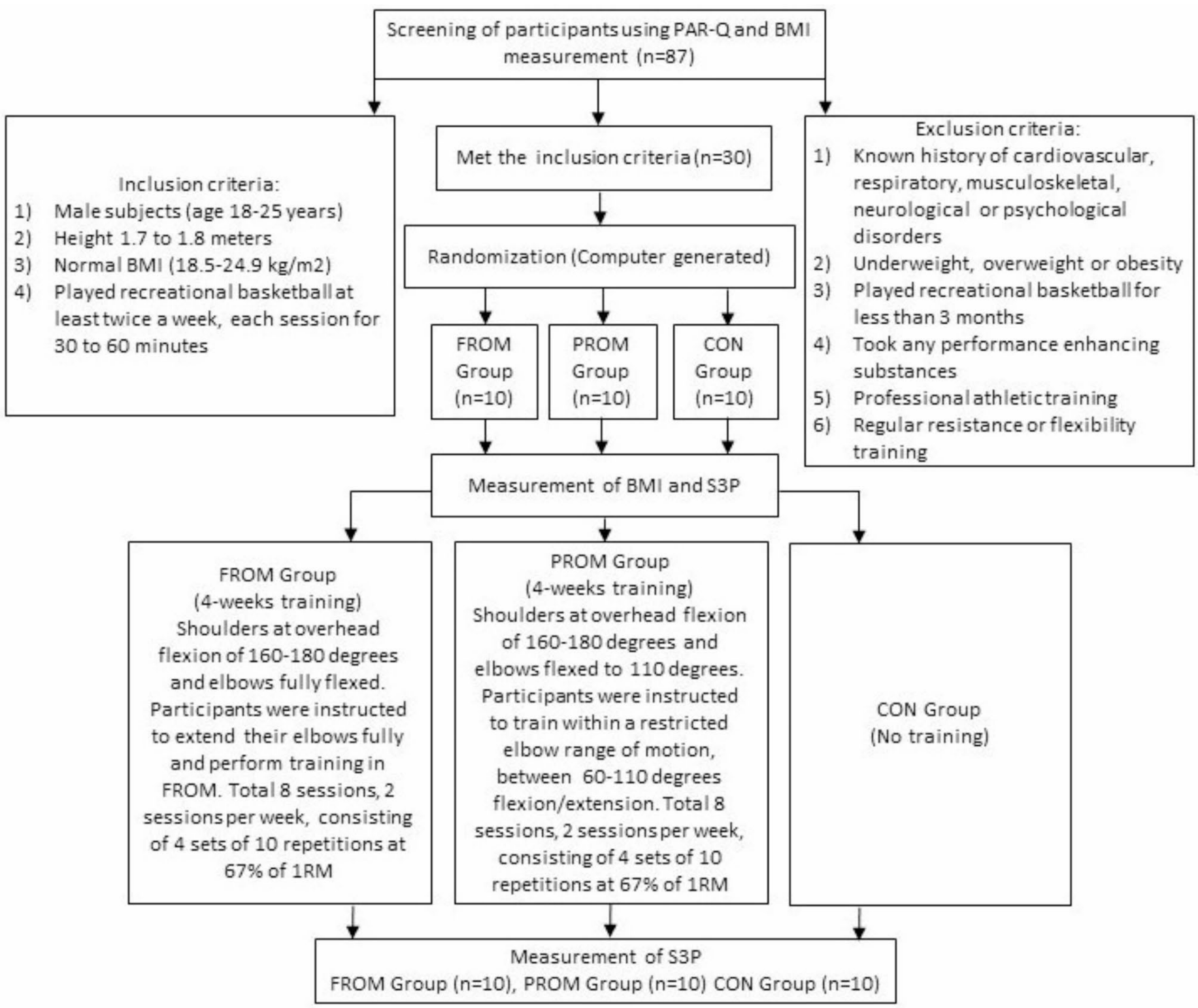

Fig. 1 CONSORT flow diagram: PAR-Q = Physical Activity Readiness Questionnaire; BMI = Body Mass Index; FROM = Full Range of Motion; PROM = Partial Range of Motion; CON = Control; S3P = Stationary Three-Point Shooting Accuracy; 1RM = 1 Repetition Maximum

portal, and emails for voluntary participation. A purposive (homogeneous) sampling technique was designed to recruit potential participants. Recruitment of the participants began on 6 January, 2019 and lasted for 14-weeks until a desired number of participants were recruited. Initially, 87 recreational basketball players were screened, and 30 fit the pre-specified eligibility criteria after measuring their body mass index (BMI – 18.5–24.9 kg/m^2) and administering the adopted physical activity readiness questionnaire (PAR-Q) to exclude any medical conditions [22]. They were randomized equally and allocated into 3 groups by applying the computer-generated block numbers; FROM, PROM, and control (CON) groups. Prior to randomization, allocation concealment was implemented through the use of sealed envelopes to prevent any potential selection bias by the investigators when assigning participants to different interventions. This approach ensured that the researchers were blinded to the treatment allocations, thereby reducing the likelihood of any intentional or unintentional influence on the assignment process.

The inclusion criteria were male subjects between the age group of 18–25 years, who played basketball at a recreational level, at least 2 times a week, each session lasting for 30–60 min, height of participants between 1.7 and 1.8 m, and a normal BMI (18.5–24.9 kg/m^2). Participants who have been playing recreational basketball for less than 3 months, taking any performance-enhancing substances, involved in any regular resistance/flexibility training or professional athletic activities, were underweight or overweight/obese, and those with any kind of cardiovascular, respiratory, neurological, psychological and/or musculoskeletal disorders were excluded from this study. Recruited participants were debriefed about the whole protocol and they were instructed not to engage in any other strength training throughout this study. Written informed consent was obtained from all the participants and the study was conducted in accordance with the Declaration of Helsinki guidelines. This study was approved by the Universiti Tunku Abdul Rahman's Scientific and Ethical Review Committee with the approval number U/SERC/134/20 and registered retrospectively on clinicaltrials.gov with the registration number NCT04128826.

Intervention protocol

Before beginning the intervention, the calculation of one-repetition maximum (1RM) for triceps curl was conducted in standing position for both FROM and PROM groups. A 5-minutes warm including dynamic stretching and controlled active movements of upper limbs were performed by all the participants prior to 1RM test. The widely recognized Mayhew's method $[1RM = 100 \times W/(52.2 + 41.9 \times e^{-0.055 \times R)}]$ was employed as the standard approach for calculating the 1RM [23]. This method is favoured due to its validity and accuracy in predicting maximum strength capacity and reduced risk of injury based on submaximal loads [24, 25]. After 1RM calculation, the intervention protocol was subsequently implemented following a structured approach to optimize the outcomes and minimize variability.

The participants in both FROM and PROM groups were instructed to stand straight with their back facing the triceps extension machine (adjustable overhead cable crossover machine 1SC120, Apiro, Italy) and not to bend their hips or knees during the training sessions. For FROM group, the height of the rope was adjusted so that the participants' shoulders were in a relaxed overhead flexion (160–180°) position and the elbows were fully flexed. Then they were instructed to extend their elbows fully and perform training in FROM (Fig. 2). FROM group carried out 4 sets of 10 repetitions at 67% of 1RM, twice weekly for 4- weeks [26]. For PROM group, exercise ROM was controlled by a plump line that was tied on top of adjustable overhead cable crossover machine 1SC120 (Apiro, Italy). Two clips were used on the plumb line, 1 marked at 60° of elbow flexion and another at 110° of elbow flexion. With the shoulders elevated to 160–180° flexion, participants in the PROM group were instructed to perform the training within a restricted elbow ROM, between 60–110° flexion/extension (Fig. 2) by observing their elbow movements in the mirror to ensure they do not exceed the points marked on plumb line. Training duration and intensity for PROM group was same as FROM group [26]. A rest period of 2-minutes was permitted for both groups between the sets to avoid fatigue setting in [27]. In addition, we conducted only two training sessions/week to avoid delayed onset muscle soreness (DOMS), as it is recommended to have a gap of at least 48–72 h for muscle recovery after the exercise [13]. Before beginning each training session and at the end of each session, a 5-minute warm-up and a 5-minute cool-down exercise were incorporated respectively comprising of stretching of biceps, triceps, pectoralis major and forearm muscles, and free ROM in sagittal and coronal planes. Participants in both experimental groups were monitored throughout the strength training to ensure they were carrying out the training protocol correctly, and no harmful or unintended effects of the intervention were reported by any of the participants from both groups. The CON group did not participate in any training program. Throughout the 4-weeks intervention, all 3 groups continued to engage in playing basketball, but they were explicitly instructed to refrain from any other form of strength or additional training activities.

Outcome measurement

In addition to measuring the BMI during the screening process, it was again recorded before beginning the intervention to ensure there were no changes in the participants' BMI. A calibrated digital seca 284 EMR (Hamburg Germany) measuring station was used to record the BMI by dividing the participants' weight by their height in square meters (kg/m^2). Participants were instructed to stand straight barefooted without any excess clothing to avoid any erroneous result. Three consecutive measurements were recorded for both height and weight to calculate the average BMI.

S3P was assessed at baseline and at end of 4-weeks of intervention. It is a reliable and validated test found to have a strong correlation extracted factor with a very good factor validity [28]. One trial was conducted to familiarize the participants before assessing the actual score and an average of 3 tests were taken as a final score. Five points were marked on the basketball court; each point 6.25 m away from the hoop (Fig. 3). First point was set at the right wing of the court, which was at 0° to the hoop, second point was set 45° away from the first point, third point at 90° facing the board and the hoop, fourth and fifth points were similar to second and first point respectively, just that the points were marked on the left side of the court. Participants shot 2 times in succession from each point, with a total of 10 points in one set. After the completion of first set, a rest period of 3-minutes was given before participants continued with set 2, similarly a rest time of 3-minutes was allowed before set 3 of the S3P test. Outcome measure was evaluated in the morning, between 9am-11am and outcome assessors were blinded to minimize the detection bias.

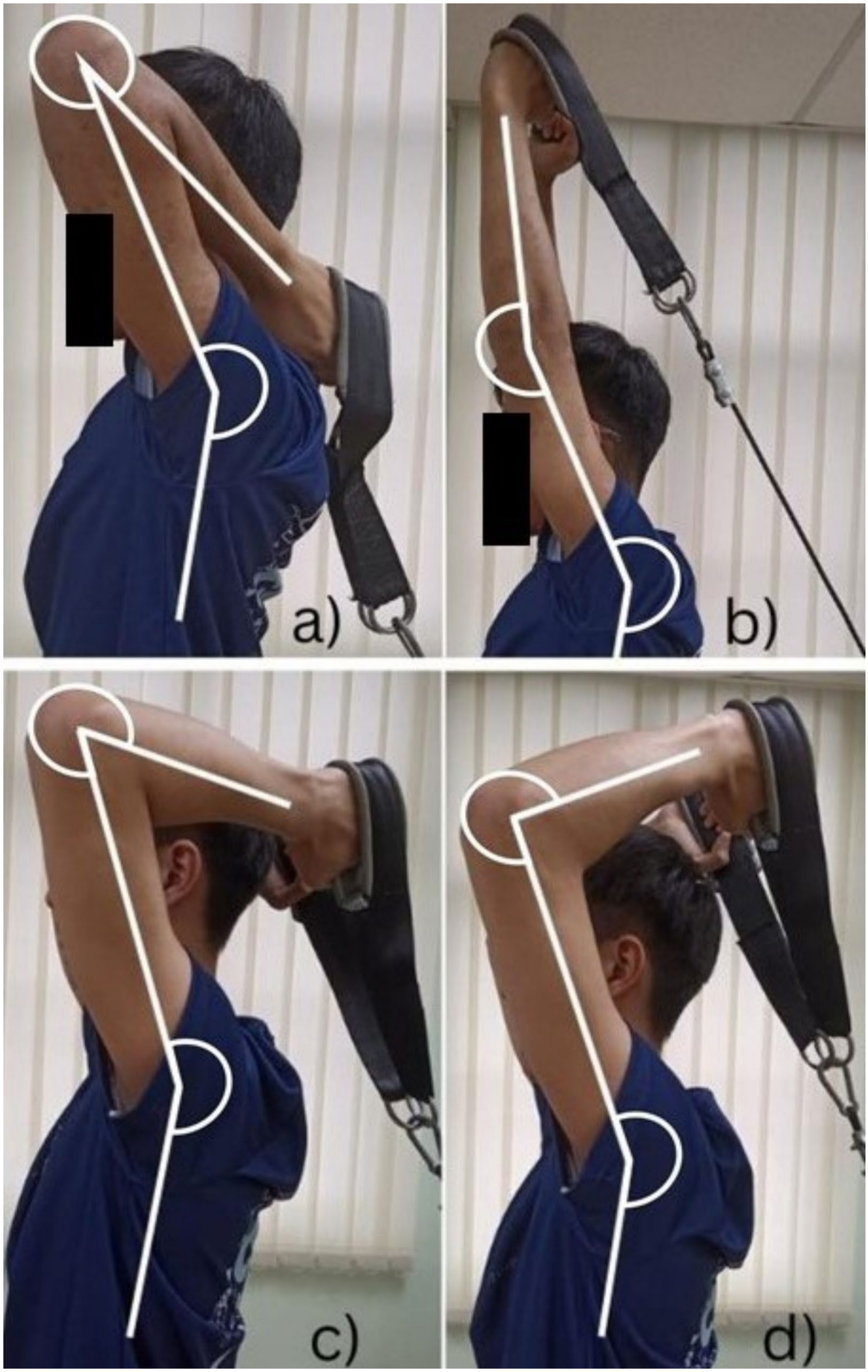

Fig. 2 Shoulder and elbow angles during training protocol: (**a**) FROM (Full range of motion) - Shoulders 160-180° flexion and elbows full flexion, (**b**) FROM - Shoulders 160-180° flexion and elbows full extension, (**c**) RROM (Partial range of motion) - Shoulders 160-180° flexion and elbows 110° flexion, (**d**) PROM - Shoulders 160-180° flexion and elbows 60° flexion

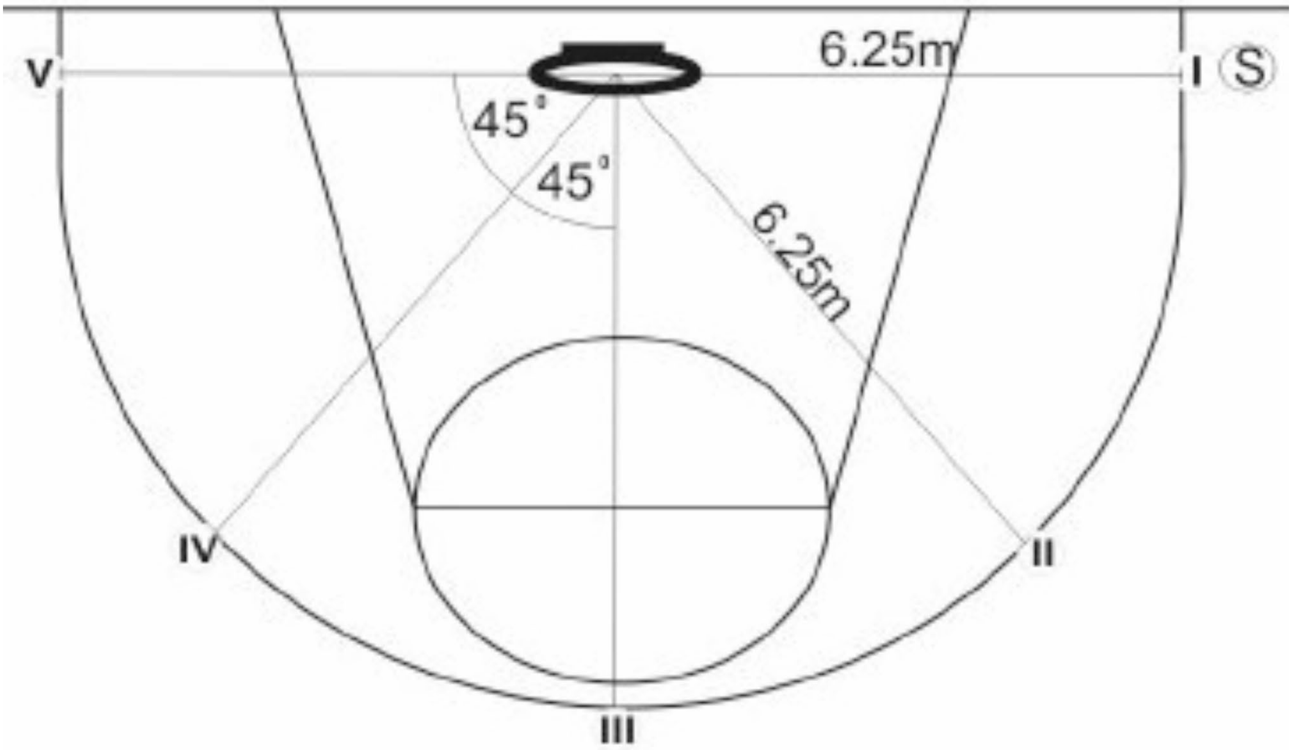

Fig. 3 Stationary three-point shooting test (S3P) Legend. S = Shooter

Table 1 Participant characteristics ($n = 30$)

Characteristics	FROM ($N = 10$) (M ± SD)	PROM ($N = 10$) (M ± SD)	CON ($N = 10$) (M ± SD)	TOTAL ($N = 30$) (M ± SD)	p-value
Age (years)	19.40 ± 1.43	20.10 ± 1.60	21.10 ± 1.20	20.20 ± 1.54	0.01
Height (m)	1.77 ± 0.04	1.74 ± 0.07	1.73 ± 0.05	1.74 ± 0.61	0.83
1RM (lbs)	51.00 ± 18.53	58.00 ± 22.01	NA	54.50 ± 20.13	0.45
Weight (kg)	63.80 ± 10.08	71.40 ± 12.39	69.50 ± 9.08	68.23 ± 10.75	0.12
BMI	20.34 ± 3.35	23.65 ± 3.55	23.66 ± 1.83	22.55 ± 3.31	0.57

Values are presented as mean ± standard deviation (SD). [a] Difference between groups

Abbreviations: 1RM (1 repetition maximum), BMI (body mass index), NA (not applicable), FROM (full range of motion), PROM (partial range of motion), CON (control)

Statistical analysis

Data collected was computerized in Microsoft Excel and analysed using the IBM Statistical Package for the Social Science Version 26.0 (SPSS Inc., Chicago, USA) software. Descriptive statistics was performed to explain the characteristics of 3 groups. A two-way repeated measure ANOVA was carried out with subsequent post-hoc Tukey test to assess the differences within and between groups. For the S3P at baseline, one-way ANOVA was performed followed by a post-hoc Tukey test to assess the differences between groups. For both ANOVA tests, the assumptions of normality and homogeneity of variances was verified using the Shapiro-Wilk test and Levene's test, respectively. Additionally, sphericity assumptions for two-way repeated measure ANOVA was assessed using Mauchly's Test of Sphericity. For all the tests, the significance level was set at $p < 0.05$.

Results

Demographics of participants

Table 1 shows the mean ± SD of the participants' demographic characteristics (age, height, weight, and BMI). None of the participants were lost or dropped out from any of the 3 groups. 1RM was measured only in participants from PROM and FROM groups as CON group did not involve in any training. There were no significant differences between the 3 groups with regards to the demographic characteristics ($p > 0.05$), except the age ($p > 0.01$).

S3P accuracy

The mean ± SD of the S3P from baseline to post-test for all groups are displayed in Table 2. At baseline, there was no significant difference between groups observed ($F_{2.27}$ = 0.05, $p = 0.9479$) as shown in the Table 3. Since there were only two levels of time point (baseline and endpoint), therefore, sphericity for two-way repeated measure ANOVA was assumed. Following 4-weeks of intervention, there was a general interaction between time and group ($F_{2.27}$ = 7.94, $p = 0.0019$), time effect ($p < 0.0001$)

Table 2 Comparison of pre- and post-test within-groups ($n = 30$)

S3P	FROM ($N = 10$)	PROM ($N = 10$)	CON ($N = 10$)
Pre-test	1.78 ± 0.65	1.75 ± 0.64	1.67 ± 1.02
Post-test	2.57 ± 1.20	3.46 ± 0.78	1.63 ± 0.51
Difference	-0.79 ± 1.00	-1.71 ± 1.03	0.14 ± 0.90
Significance	0.0345*	0.0005*	0.8995
95% CI	-1.50 to -0.07	-2.44 to -0.97	-0.61 to 0.68
ES	0.81	2.40	0.05

Values are presented as mean ± standard deviation (SD). * Difference within groups

Abbreviations: S3P (stationary three-point shooting accuracy), ES (effect size: large > 0.8, medium > 0.5, small > 0.2), CI (confidence interval), FROM (full range of motion), PROM (partial range of motion), CON (control)

Table 3 Comparison of pre-test (S3P) between all groups ($n = 30$)

S3P	I Group	J Group	Difference (i-j)	*p*-value	95%CI
	FROM	PROM	0.03	0.99	-0.84 to 0.90
		CON	0.11	0.95	-0.76 to 0.99
	PROM	FROM	-0.03	0.99	-0.90 to 0.85
		CON	0.08	0.97	-0.79 to 0.96
	CON	FROM	-0.11	0.95	-0.99 to 0.76
		PROM	-0.08	0.97	-0.96 to 0.79

One-way ANOVA performed followed by post-hoc Tukey test

Values are presented as mean difference. [a] Difference between groups

Abbreviations: S3P (stationary three-point shooting accuracy), CI (confidence interval), FROM (full range of motion), PROM (partial range of motion), CON (control)

and group effect ($p = 0.0139$) observed. When analysing the result of within-groups, there was significant difference between pre- and post-test in FROM (t_9 = -2.49, $p = 0.0345$, *95% CI* = -1.50 to -0.07, $ES = 0.81$) and PROM (t_9 = -5.25, $p = 0.0005$, *95% CI* = -2.44 to -0.97, $ES = 2.40$), but not observed in CON ($t_9 = 0.13$, $p = 0.8995$, *95% CI* = -0.61 to 0.68, $ES = 0.05$). These analyses indicate that strengthening exercise in FROM and PROM improves the basketball shooting accuracy (Fig. 4). FROM had a mean difference of -0.79 ± 1.00 from pre-test to post-test, PROM showed a mean difference of -1.71 ± 1.03, while CON demonstrated a difference of 0.14 ± 0.90 from baseline to post-test. PROM group achieved a greater effect size (2.40) compared to the other two groups.

Based on the analysis of between group differences (Table 4), there was a significant change observed between the PROM and CON ($p = 0.0102$, *95% CI* = -1.70 to -0.21), but not between other paired groups. This finding shows that triceps strength training in PROM is superior in improving shooting accuracy compared to FROM and CON, as there was no significant difference observed between FROM and CON (Fig. 4). In addition, CON and FROM had a small and medium effect size (0.05 and 0.81 respectively), compared to PROM, which had a large effect size of 2.40.

Discussion

Previously, the majority of studies have focused on measuring the isokinetic strength at different speed points with shooting accuracy. Despite the availability of numerous training methods, the optimal method to improve shooting accuracy among basketball players remains uncertain. This indicates the scarcity in the existing literature and addresses the need to explore triceps strength training using partial range exercises. This study aimed to compare the effect of triceps strength training in FROM and PROM on S3P among recreational basketball players. Findings indicated that triceps strength training in PROM is more effective in improving the shooting accuracy at S3P when compared to FROM and CON. Although both PROM and FROM training improved the shooting accuracy, when compared with the CON group, FROM failed to reach significant improvements.

RT conducted in PROM increases the triceps strength which is similar to previously reported studies [12, 29]. Although triceps strength has been associated with shooting accuracy, no previous study has explored the effect of triceps strength training performed in different ranges of motion on improving sports performance, particularly the S3P [30]. Therefore, a comparison of findings to this study was deemed impossible. The possible explanation for triceps strength training carried out in PROM that improved S3P is that triceps PROM mimics the S3P movement, and PROM increases the strength of the medial head of triceps brachii, where the muscle is most activated in S3P [16, 20]. During the S3P, shoulders are elevated above 90° and elbow flexion is close to 90° (Fig. 5), and in this position the medial head of triceps is activated (Fig. 6) the most [16, 20, 31]. These findings are supported by a previous study, in which electromyographic findings indicate that when a basketball is lifted overhead and propelled forward towards the basket, the triceps brachii is activated and the antagonist muscles cooperate in the movement [32]. An earlier study showed that the elbow had very little influence in any of the postures evaluated and that the elevation of the shoulder is the most crucial component in determining the triceps brachii influence on shoulder extension moments [33].

The concept of specificity states that neural adaptations occur with persistent training specific to the ROM that eventually leads to higher adaptations within the functional training range [6]. Adaptations resulting from short-term RT are primarily attributed to neural mechanisms. These neural adaptations include enhanced neuromuscular activation of the agonist muscles and synchronized motor unit recruitment [34, 35]. It is proposed that training a muscle at specific joint angles may promote greater neural adaptations and increase the force production which may improve the sport's specificity and performance [29, 36, 37]. This finding is further

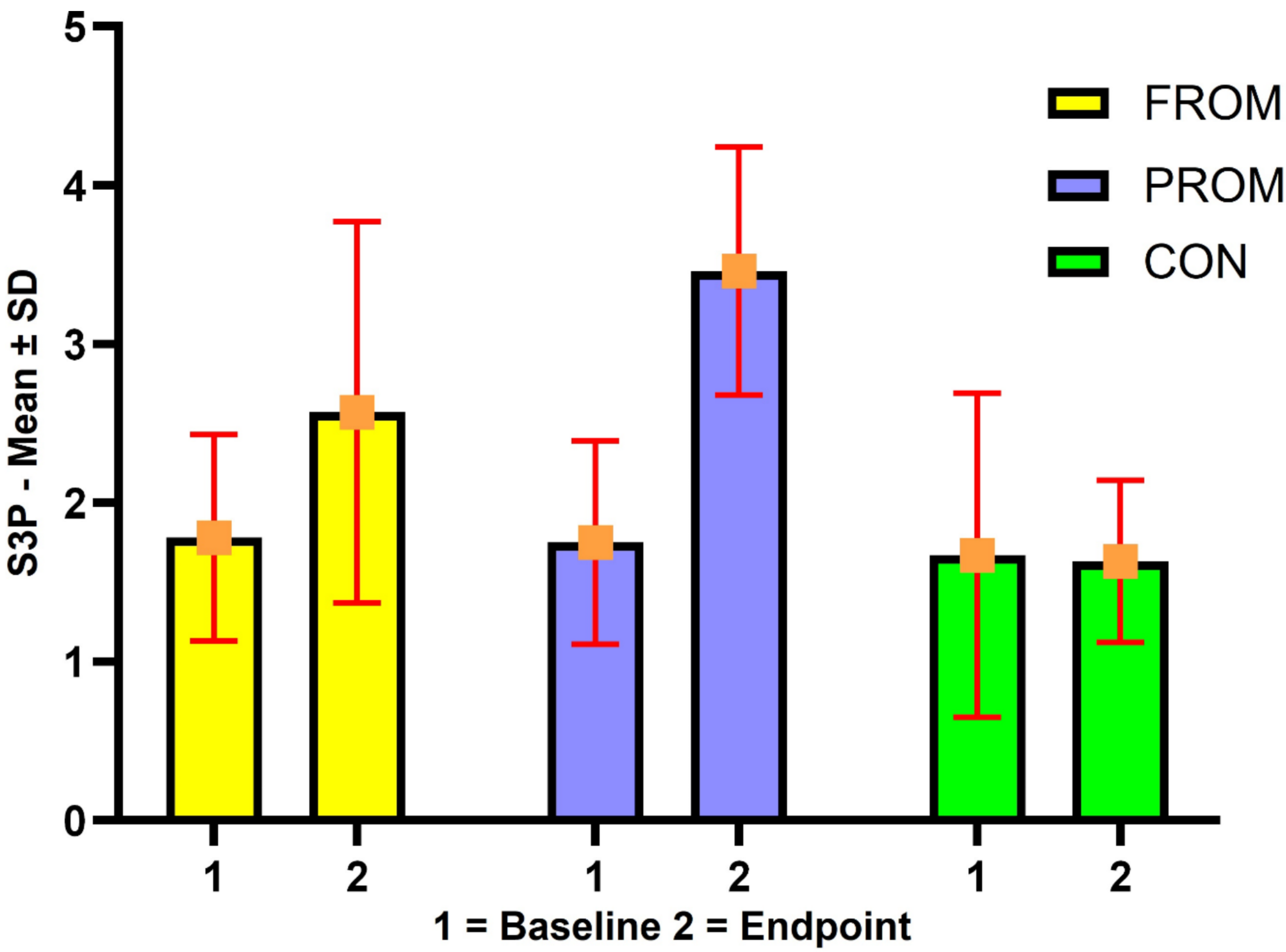

Fig. 4 A significant main effect of time (FROM: $p = 0.0345$ and PROM: $p = 0.0005$) and a significant group-by-time interaction effect (PROM: $p = 0.0102$) on S3P. Abbreviation: FROM = Full range of motion, RROM = Partial range of motion, CON = Control, S3P = Stationary three-point shooting accuracy, SD = Standard deviation

Table 4 Comparisons of post-test (S3P) between all groups ($n = 30$)

S3P	I Group	J Group	Difference (i-j)	*p*-value	95%CI
	FROM	PROM	-0.43	0.34	-1.18 to 0.31
		CON	0.52	0.21	-0.22 to 1.27
	PROM	FROM	0.43	0.34	-0.32 to 1.18
		CON	0.96	0.01*	0.21 to 1.70
	CON	FROM	-0.52	0.21	-1.27 to 0.22
		PROM	-0.96	0.01*	-1.70 to -0.21

Repeated measures ANOVA performed followed by post-hoc Tukey test

Values are presented as mean difference. * Difference between groups

Abbreviations: S3P (stationary three-point shooting accuracy), CI (confidence interval), FROM (full range of motion), PROM (partial range of motion), CON (control)

corroborated by a study by Maeo et al. (2013), which demonstrated that a 4-weeks of training involving maximal voluntary co-contraction of the elbow flexors and extensors resulted in significant improvement in force production. This enhancement was primarily attributed to increased neuromuscular adaptations, including improvement in the neural signalling and efficiency of muscle coordination [38]. In addition, resistance training at PROM has been suggested as a good strategy to reduce neural inhibition and improve the coordination of primary and stabilizing muscles [39]. S3P involves a complex sequence of kinetic chains, and we hypothesize that improvement in the triceps intramuscular coordination and longer muscle activation time as a result of neural adaptation by strength training in the targeted PROM is one of the important contributing factors to the success of three-point shooting. Intramuscular coordination is achieved by performing many repetitions of the same movement with a moderate to high load between 40 and 80% of 1RM [40]. Basketball players need to coordinate the movement and generate an adequate amount of force to score proficiently. Therefore, utilising the force correctly in a coordinated manner with a low variability of triceps muscle activation is the key to S3P, and it is difficult for an athlete to score without having enough strength and good intramuscular coordination in the triceps brachii [32, 40]. Moreover, the repetitive

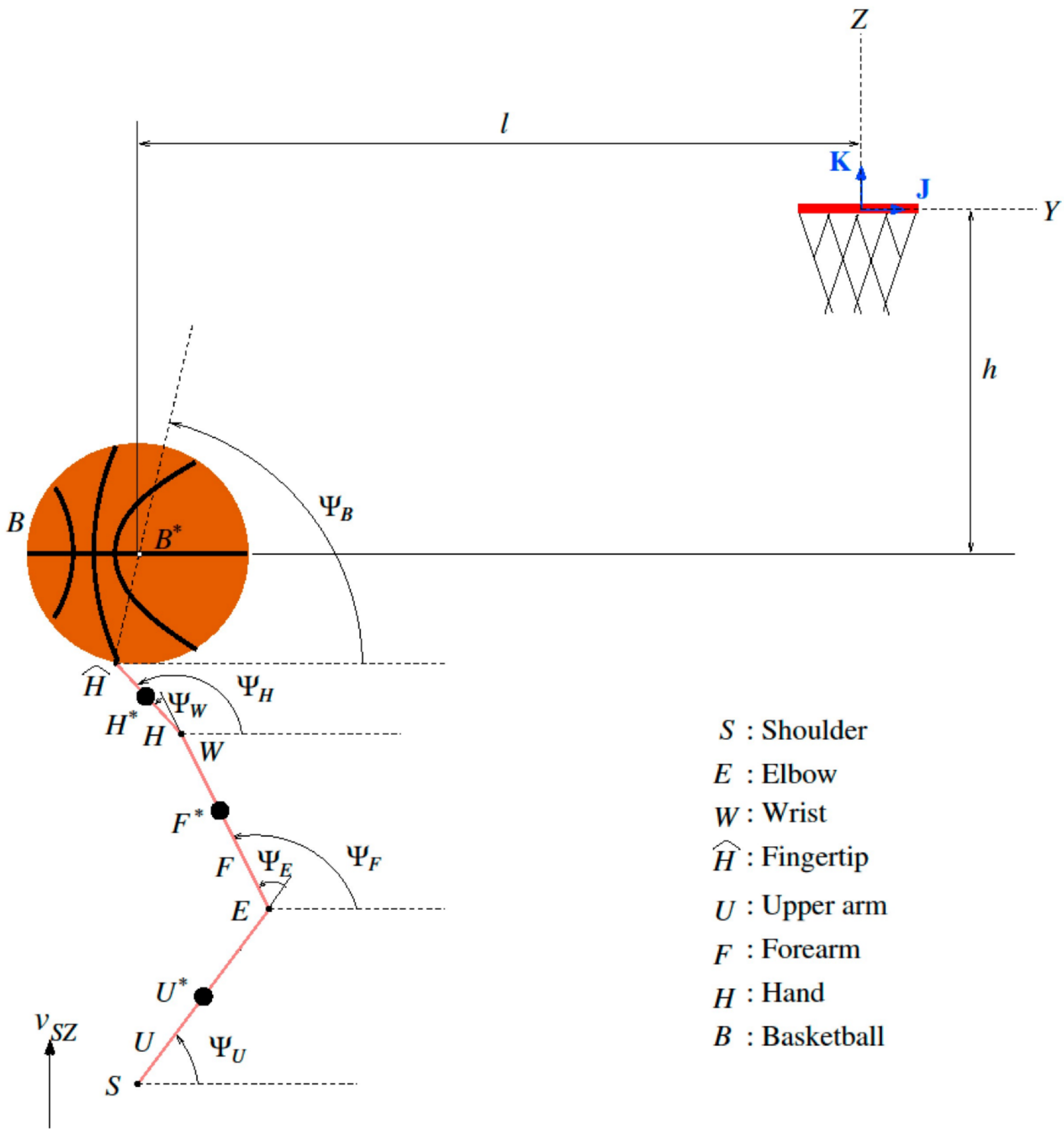

Fig. 5 Geometry of shooting arm (Okubo H., 2020)

arm movements expose untrained basketball players to fatigue, which could be detrimental to shooting accuracy [41]. Understanding and applying these basic principles may help basketball players to be successful because imbalanced force generation and shorter muscle activation time can lead to inaccuracy and fatigue, and thus reduce the shooting accuracy and scoring ability. Fatigue, in particular, has been found to have a profound effect on position release as it reduces the shoulder height while attempting the shot at the basket [42]. We postulate that 4-weeks of triceps strength training in the partial range (shoulders 160–180° flexion, elbows 60–110° flexion/extension) mimicking the basketball shooting action might have helped in gaining sufficient strength and increased the muscle activation time, thus contributing to enhanced triceps intramuscular coordination that eventually improved the S3P score in the PROM group compared to the other 2 groups.

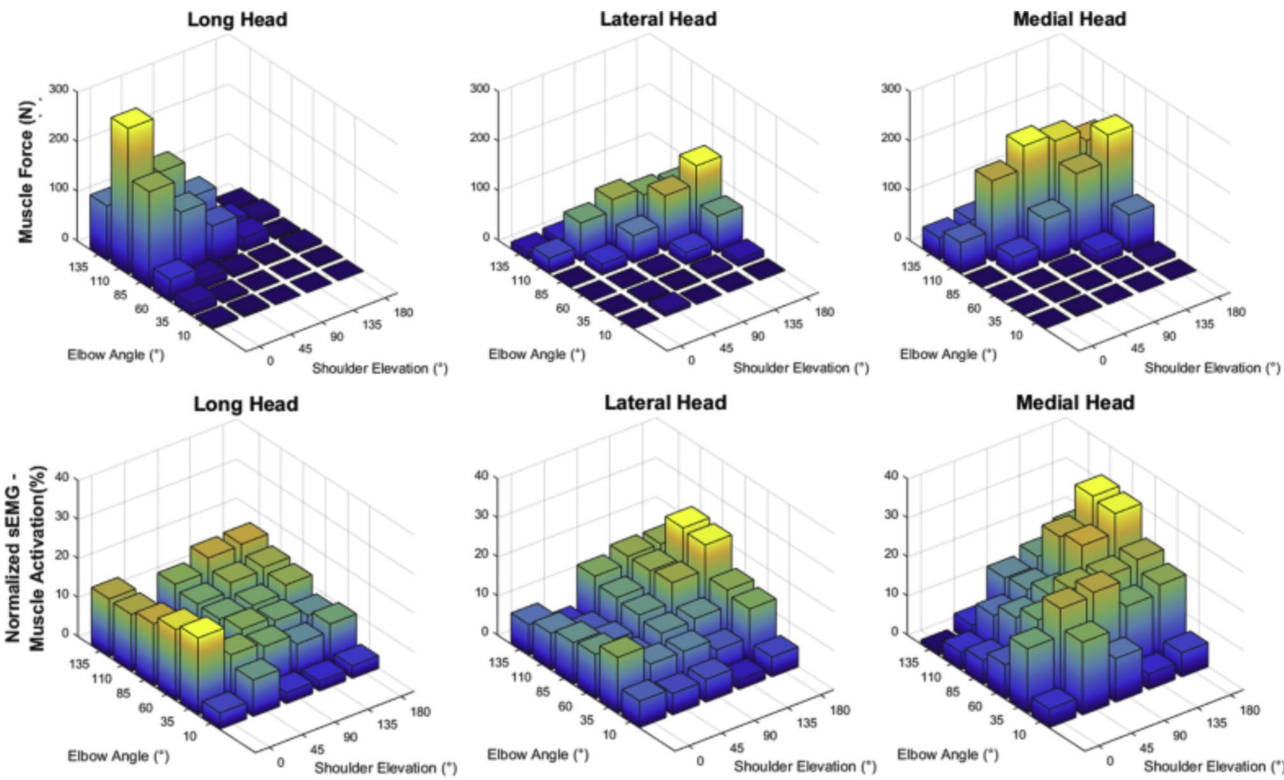

Fig. 6 Activation of triceps brachii muscle fibres in relation to shoulder and elbow range of motion (Kholinne, E., et al. 2018)

In general, 60–80% of 1RM training intensity is advisable for increasing muscle mass and strength [43]. According to research, PROM exercises can be done to increase muscular strength and hypertrophy after a training session for technical skill improvement. Muscle time under strain and muscle activation are some intriguing potential mechanisms and outcomes of interest. The PROM resistance training exercise allows athletes and coaches to provide a unique metabolic stimulus that promotes increased muscular strength and hypertrophy responses in comparison to FROM [44]. Recent studies have suggested that the PROM training approach may produce muscle hypertrophy adaptations similar to the conventional FROM resistance training. However, this technique needs to be further investigated for any potential mechanisms that may isolate and explain these similar findings [45]. There is probably no "one size fits all" method for training ROM for various sports or movement patterns. When an athlete or trainee has a musculoskeletal problem, for instance, loading a muscle through a FROM may exaggerate pain, PROM training may be advantageous. It is unknown if and when employing various ranges of motion may have various effects in terms of morphology and/or musculoskeletal function [46].

Limitations and recommendations

There are a few limitations to the present study that should be addressed. Firstly, the effects of triceps strength training were limited to 4-weeks only, whereby the long-term effects of triceps strength training done at different ranges of motion remain unclear. Secondly, the strength gained following the strength training was not considered. Future studies should consider the long-term effect of triceps strength training at different ranges of motion on shooting accuracy and the association between strength gain and shooting accuracy. In addition, only 1 test was implemented to evaluate shooting accuracy in this study; therefore, we suggest using more than 1 test in future studies to validate the shooting accuracy. Finally, the measurement outcomes obtained from recreational players may not accurately reflect the physiological, biomechanical, or performance characteristics of professionals, given the differences in training intensity, skill level, and physical conditioning. Hence, future researchers should prioritize studies involving professional basketball players to ensure that the training protocols and injury prevention strategies are evidence-based and specifically tailored to meet the athlete's unique demands.

Conclusions

Shooting often involves a shoulder elevation angle close to 160–180°, especially during jump shots or free throws. During a basketball shot, the triceps play a pivotal role in extending the elbow, which is the final motion that propels the ball towards the basket. Strengthening the triceps in the shooting-specific ROM allows for greater force production and control during this critical phase of the shot. Our study findings demonstrate that a 4-week program of PROM training, with shoulders over-head flexed to 160–180°, and focusing on triceps strength training within a restricted range between 60–110° of elbow flexion/extension is a time-efficient method for improving the S3P accuracy among recreational basketball players. Training in this position ensures that the muscles and joints adapt to the specific angles encountered during gameplay, enhancing the shooting form, consistency, and accuracy. Therefore, PROM triceps strength is recommended to be integrated into the training program of recreational basketball players. Coaches and professional basketball players may incorporate the same training protocol into their regimen that emphasizes targeted shoulder and elbow ROM exercises. This approach can evaluate the practicality of PROM training and its effect on shooting accuracy, potentially highlighting areas for improvement or modifications to better suit the specific needs of individual basketball players.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13102-025-01060-2.

Supplementary Material 1

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Author contributions

The study concept was developed by I.A.M. Study design was carried out by I.A.M. and M.N.Z.M.J. Data collection was conducted by T.A. and C.K.W. Implementation of intervention was executed by C.K.W. and M.N.Z.M.J. Data analyses and interpretation was performed by I.A.M., M.N.Z.M.J. and S.H. Initial manuscript drafting was carried out by I.A.M, S.H., C.K.W. and M.N.Z.M.J. Critical review of the manuscript draft was performed by T.A. and S.H. and M.S.S. All authors read and approved the final version of the manuscript.

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Data availability

All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate

This study was approved by Universiti Tunku Abdul Rahman's (UTAR) Scientific and Ethical Review Committee with the approval number U/SERC/134/20. Written informed consent to participate in this study was obtained from all the participants.

Consent for publication

Written consent for publication was obtained from the participants shown in Fig. 2.

Competing interests

The authors declare no competing interests.

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References

1. American College of Sports Medicine. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc. 2009;41(3):687–708.
2. Pinto RS, Gomes N, Radaelli R, Botton CE, Brown LE, Bottaro M. Effect of range of motion on muscle strength and thickness. J Strength Cond Res. 2012;26(8):2140–5.
3. Hawley JA. Adaptations of skeletal muscle to prolonged, intense endurance training. Clin Exp Pharmacol Physiol. 2002;29(3):218–22.
4. Krzysztofik M, Matykiewicz P, Filip-Stachnik A, Humińska-Lisowska K, Rzeszutko-Bełzowska A, Wilk M. Range of motion of resistance exercise affects the number of performed repetitions but not a time under tension. Sci Rep. 2021;11(1):14847.
5. McMahon GE, Morse CI, Burden A, Winwood K, Onambélé GL. Impact of range of motion during ecologically valid resistance training protocols on muscle size, subcutaneous fat, and strength. J Strength Cond Res. 2014;28(1):245–55.
6. Schoenfeld BJ, Grgic J. Effects of range of motion on muscle development during resistance training interventions: a systematic review. SAGE Open Med. 2020;8:2050312120901559.
7. Bazyler CD, Sato K, Wassinger CA, Lamont HS, Stone MH. The efficacy of incorporating partial squats in maximal strength training. J Strength Cond Res. 2014;28(11):3024–32.
8. Bloomquist K, Langberg H, Karlsen S, Madsgaard S, Boesen M, Raastad T. Effect of range of motion in heavy load squatting on muscle and tendon adaptations. Eur J Appl Physiol. 2013;113(8):2133–42.
9. Fleck SJ, Kraemer WJ. Resistance training: Basic principles (part 1 of 4). Phys Sportsmed. 1988;16(3):160–71.
10. Graves JE, Pollock ML, Jones AE, Colvin AB, Leggett SH. Specificity of limited range of motion variable resistance training. Med Sci Sports Exerc. 1989;21(1):84–9.
11. Paoli A, Marcolin G, Petrone N. Influence of different ranges of motion on selective recruitment of shoulder muscles in the sitting military press: an electromyographic study. J Strength Cond Res. 2010;24(6):1578–83.
12. Massey CD, Vincent J, Maneval M, Moore M, Johnson JT. An analysis of full range of motion vs. partial range of motion training in the development of strength in untrained men. J Strength Cond Res. 2004;18(3):518–21.
13. Baroni BM, Pompermayer MG, Cini A, Peruzzolo AS, Radaelli R, Brusco CM, et al. Full range of Motion induces Greater muscle damage than partial range

of motion in Elbow Flexion Exercise with Free weights. J Strength Cond Res. 2017;31(8):2223–30.
14. Järvinen TAH, Järvinen TLN, Kääriäinen M, Kalimo H, Järvinen M. Muscle injuries: biology and treatment. Am J Sports Med. 2005;33(5):745–64.
15. Maffulli N, Del Buono A, Oliva F, Giai Via A, Frizziero A, Barazzuol M, et al. Muscle injuries: a brief guide to classification and management. Transl Med UniSa. 2014;12:14–8.
16. Okubo H, Hubbard M. Kinematics of Arm Joint motions in basketball shooting. Procedia Eng. 2015;112:443–8.
17. Physiopedia [Internet]. [cited 2024 Dec 17]. Biomechanics of the Basketball Jump Shot. Available from: https://www.physio-pedia.com/Biomechanics_of_the_Basketball_Jump_Shot
18. Cao S, Liu J, Wang Z, Geok SK. The effects of functional training on physical fitness and skill-related performance among basketball players: a systematic review. Front Physiol [Internet]. 2024 May 9 [cited 2024 Dec 17];15. Available from: https://www.frontiersin.org/journals/physiology/articles/https://doi.org/10.3389/fphys.2024.1391394/full
19. Ahn N, Kipp K, A PILOT STUDY OF ELBOW-SHOULDER COORDINATION PATTERNS, DURING 3-POINT SHOTS IN PLAYERS OF DIFFERENT SKILL LEVELS. ISBS Proc Arch [Internet]. 2023;41(1). Available from: https://commons.nmu.edu/isbs/vol41/iss1/5
20. Kholinne E, Zulkarnain RF, Sun YC, Lim S, Chun JM, Jeon IH. The different role of each head of the triceps brachii muscle in elbow extension. Acta Orthop Traumatol Turc. 2018;52(3):201–5.
21. Tyagi M, Pal S, Yadav J, Kalra S. Effectiveness of eight-week Variable Resistance Training on Ball Release Speed, Jump Height, Speed of Upper Limb Performance, and Accuracy in Young Collegiate Basketball players. Med J Dr Patil Univ. 2024;17(4):722.
22. Shephard RJ. PAR-Q, Canadian Home Fitness Test and Exercise Screening Alternatives. Sports Med. 1988;5(3):185–95.
23. Mayhew JL, Ball TE, Arnold MD, Bowen JC. Relative muscular endurance performance as a Predictor of Bench Press Strength in College men and women. J Strength Cond Res. 1992;6(4):200.
24. Ribeiro A, da Silva JA, Nascimento M, Martinho D, Santos L, de dos, Salles B et al. Accuracy of 1RM Prediction Equations Before and After Resistance Training in Three Different Lifts. Int J Strength Cond [Internet]. 2024 Oct 4 [cited 2024 Dec 31];4(1). Available from: https://journal.iusca.org/index.php/Journal/article/view/327
25. Moses T, Haggie M. The Validity of 1-RM Equations in the Bench Press, Squat and Deadlift.
26. Drinkwater EJ, Moore NR, Bird SP. Effects of changing from full range of motion to partial range of motion on squat kinetics. J Strength Cond Res. 2012;26(4):890–6.
27. Baechle TR, Earle RW. Essentials of Strength Training and Conditioning. 2nd ed. Champaign, IL: Human Kinetics; 2000. pp. 395–425.
28. Pojskic H, Separovic V, Uzicanin E. Reliability and factorial validity of basketball shooting accuracy tests. Sport Sci Pract Asp. 2011;8(1):25–32.
29. Clark RA, Bryant AL, Humphries B. An examination of strength and concentric work ratios during variable range of motion training. J Strength Cond Res. 2008;22(5):1716–9.
30. Tang WT, Shung HM. Relationship between isokinetic strength and shooting accuracy at different shooting ranges in Taiwanese elite high school basketball players. Isokinet Exerc Sci. 2005;13(3):169–74.
31. Okubo H, Hubbard M. Analysis of Arm Joint torques at Ball-Release for Set and Jump shots in basketball. Proceedings. 2020;49(1):4.
32. Pakosz P, Domaszewski P, Konieczny M, Bączkowicz D. Muscle activation time and free-throw effectiveness in basketball. Sci Rep. 2021;11(1):7489.
33. Landin D, Thompson M. The shoulder extension function of the triceps brachii. J Electromyogr Kinesiol. 2011;21(1):161–5.
34. Gabriel DA, Kamen G, Frost G. Neural adaptations to resistive Exercise. Sports Med. 2006;36(2):133–49.
35. Folland JP, Williams AG. Morphological and neurological contributions to increased strength. Sports Med. 2007;37(2):145–68.
36. Noorkõiv M, Nosaka K, Blazevich AJ. Neuromuscular Adaptations Associated with Knee Joint… Medicine & Science in Sports & Exercise. [cited 2024 Dec 27]; Available from: https://journals.lww.com/acsm-msse/fulltext/2014/08000/neuromuscular_adaptations_associated_with_knee.7.aspx
37. Kubo K, Ohgo K, Takeishi R, Yoshinaga K, Tsunoda N, Kanehisa H, et al. Effects of isometric training at different knee angles on the muscle-tendon complex in vivo. Scand J Med Sci Sports. 2006;16(3):159–67.
38. Maeo S, Yoshitake Y, Takai Y, Fukunaga T, Kanehisa H. Effect of short-term maximal Voluntary co-contraction training on neuromuscular function. Int J Sports Med. 2013;35:125–34.
39. Pallarés JG, Hernández-Belmonte A, Martínez-Cava A, Vetrovsky T, Steffl M, Courel-Ibáñez J. Effects of range of motion on resistance training adaptations: a systematic review and meta-analysis. Scand J Med Sci Sports. 2021;31(10):1866–81.
40. Bompa TO, Buzzichelli C. Periodization of Strength Training for sports. 4th ed. Human Kinetics; 2022.
41. Mulazimoglu O, Yanar S, Tunca Evcil A, Duvan A. Examining the effect of fatigue on shooting accuracy in young basketball players. Anthropol. 2017;27(1–3):77–80.
42. Erculj F, Supej M. Impact of fatigue on the position of the release arm and shoulder girdle over a longer shooting distance for an elite basketball player. J Strength Cond Res. 2009;23(3):1029–36.
43. Nakamura M, Yoshida T, Kiyono R, Sato S, Takahashi N. The effect of low-intensity resistance training after heat stress on muscle size and strength of triceps brachii: a randomized controlled trial. BMC Musculoskelet Disord. 2019;20:603.
44. Ozimek M, Ambroży T, Krasavina T, Lazareva I, Popova C, Rydzik Ł, et al. Acute effects of Partial Range of Motion Resistance Training and increases in blood lactate impact accuracy of Penalty kicks in Soccer players. BioMed Res Int. 2022;2022:4769560.
45. Newmire DE, Willoughby DS. Partial compared with full range of Motion Resistance Training for muscle hypertrophy: a brief review and an identification of potential mechanisms. J Strength Cond Res. 2018;32(9):2652–64.
46. Wolf M, Androulakis-Korakakis P, Fisher J, Schoenfeld B, Steele J. Partial Vs Full Range of Motion Resistance Training: A Systematic Review and Meta-Analysis. Int J Strength Cond [Internet]. 2023 Mar 2 [cited 2023 Apr 4];3(1). Available from: https://journal.iusca.org/index.php/Journal/article/view/182

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