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The Role of Training in Muscle Fiber Type Composition Changes Among Petanque Athletes in Soppeng

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ABSTRACT
Background: Petanque is a precision sport requiring fine motor neuromuscular control, postural stability, and limb strength-endurance. Despite growing popularity in Soppeng Regency, South Sulawesi, scientific evidence on structured training effects on muscle fiber composition in petanque athletes remains scarce. Objectives: This study analyzed muscle fiber type composition changes among 36 Soppeng petanque athletes (18 male, 18 female) following a 12-week periodized training program, comparing adaptations across competition categories (buts, tir, mele). Methods: A quasi-experimental pre-test/post-test design was applied to three groups (n=12 each). Measures included handgrip dynamometry, one-leg stance, isokinetic wrist strength, shoulder endurance, 30-meter sprint, VO_2max, and ultrasound CSA of m. flexor digitorum superficialis and m. deltoid. Results: All groups showed significant improvements ($p<0.05$). Buts athletes demonstrated superior gains in handgrip (+18.4%), balance (+42.3%), and wrist endurance (+31.2%), reflecting Type I fiber dominance. Tir athletes showed greater shoulder explosive power (+24.6%) and sprint improvement (-6.8%), indicating Type II hypertrophy. Mele athletes exhibited balanced adaptations. Conclusions: Petanque-specific training produces category-dependent muscle fiber adaptations, providing the first empirical evidence base for petanque muscle physiology in Soppeng.

Keywords: Muscle Fiber Composition; Petanque; Soppeng; Training Adaptation; Type I; Type II; Precision Sport; Neuromuscular Control.

INTRODUCTION

Petanque is a precision sport that originated in France and has now become an official sport contested in the Indonesian National Sports Week (PON). Soppeng Regency in South Sulawesi has shown rapid petanque development in the past decade, with a number of its athletes successfully penetrating the national competition level. Unlike team sports that require dominant physical capacity in the form of speed or high aerobic endurance, petanque is a sport dominated by fine motor control, movement precision, postural stability, and upper extremity endurance strength, especially in the wrist, elbow, and shoulder joints (Crespo et al., 2019).

From the perspective of sports physiology, the unique demands of petanque put it in a very different position from conventional strength and endurance sports. The throwing motion of a boule on a petanque involves a highly coordinated contraction of complex kinetic chains: m. gluteus maximus and m. erector spinae for stabilization of the body; M. deltoid anterior and M. pectoralis major for arm swing; M. biceps brachii and M. brachioradialis for elbow flexion control; and M. flexor digitorum superficialis and profundus for precise grip and release of boule. The contractions involved are submaximal but with very high demands on motor precision, so it is predicted to recruit mainly Type I (slow-twitch, oxidative) and Type IIa (fast oxidative glycolytic) fibers rather than pure glycolytic IIx fibers (Schiaffino & Reggiani, 2011).

The petanque branch has three main categories of competitions that demand different physical and neuromuscular profiles: (1) Buts (pointer/pointeur) throws boule as close as possible to the cochonnet (jack), demanding the highest precision and repetitive smooth control; (2) Tir (shooter/tireur) shoots the opponent's boule with speed and accuracy, demanding explosive power and consistency of technique; and (3) Mele (milieu) plays the role of a versatile player who masters both techniques. These differences in technical demands will logically result in different adaptations of muscle fibers and neuromuscular profiles when athletes undergo position-specific training programs.

Although petanque has been extensively researched from a technical and psychological perspective, in-depth physiological studies of the composition of muscle fiber types and their adaptation to training in petanque athletes, especially in Indonesia, are still very limited. Studies at the international level are also generally conducted on elite athletes from European and East Asian countries who have anthropometric characteristics, training culture, and environment that are different from athletes in South Sulawesi. Soppeng, with its strong petanque tradition and the availability of a thriving training infrastructure, is an ideal location for this study.

This study aims to: (1) analyze the role of structured exercise in changing muscle fiber type composition indicators in Soppeng petanque athletes after 12 weeks of a periodized training program; (2) comparing the amount of adaptation between competition categories (buts, tir, mele); (3) identify differences in adaptation responses between male and female athletes; and (4) provide evidence-based recommendations for the development of a petanque training program in Soppeng that supports improvement of achievement at the regional and national levels.

METHODS

Research Design

This study uses a quasi-experimental design with a pre-test and post-test design of three groups based on the petanque competition category. All groups underwent a 12-week periodized petanque training program with different component emphasis according to the demands of their respective categories. The free variable is the competition category (buts, tir, mele), while the bound variable is an indicator of muscle fiber type composition measured through strength, endurance, neuromuscular precision, and muscle ultrasound tests.

Population and Sample

The study population was all active petanque athletes registered in petanque clubs in Soppeng Regency (N = 74). Samples were selected using purposive sampling techniques with inclusion criteria: (1) age 17–35 years; (2) actively practicing petanque for at least 1.5 years; (3) have no history of upper extremity injury in the last 6 months; (4) not in a medical condition that affects neuromuscular function; and (5) be willing to participate fully for 12 weeks. From the selection, 36 athletes (18 men, 18 women) were selected which were divided according to the main competition category: Buts (n=12; 6 men, 6 women), Tir (n=12; 6 men, 6 women), and Mele (n=12; 6 men, 6 women). Power analysis calculations confirmed the adequacy of the sample (power = 0.80; $\alpha = 0.05$; effect size f = 0.40). All participants signed written informed consent, and the research protocol has been approved by the UPRI Research Ethics Committee (No. 072/KEP-UPRI/2024).

Training Protocol

The 12-week periodized training program is divided into three phases designed with the Soppeng Regency petanque coaching team: (1) Foundation Phase (weeks 1–4): medium volume, low-medium intensity focus on basic physical conditions (flexibility, postural stability, functional strength), basic throwing techniques, and drill footwork. Practice sessions 4 times per week, 90 minutes per session; (2) Development Phase (weeks 5–8): medium-high volume, medium-high intensity category-specific exercise emphasis: buts intensify repetitive precision drills (200–400 throws per session) and proprioception; tir intensifies shoulder-arm explosive strength exercises and target fire drills; Mele combines the two. Sessions 5 times per week; (3) Stabilization Phase (weeks 9–12): reduced volume, high-submaximum intensity focus on technique consistency,

match simulation, and peaking. Sessions 4 times per week. All groups received a joint physical fitness session 2 times per week which included aerobic exercises, core stability, and stretching.

Measurement Instruments

Changes in the composition of muscle fiber types were studied through validated performance instruments: (1) Handgrip Dynamometry (Jamar hydraulic dynamometer) to measure maximum grip strength as a representation of the intrinsic strength of the hand and finger flexor fibers; (2) Wrist Flexor-Extensor Isokinetic Strength (isokinetic dynamometer, 60°/sec) to assess the strength and endurance of the wrist muscles; (3) Shoulder Rotator Cuff Endurance Test (maximum reps at 30% body weight, 90° abduction) as an indicator of the endurance of Type I shoulder muscle fibers; (4) Shoulder Explosive Power Test (medicine ball chest throw, 2 kg) to assess the explosive strength of Type II deltoid and pectoralis fibers; (5) One-Leg Stance Test (open and closed eyes) to measure postural stability and proprioceptive ability controlled by Type I fibers of postural muscles; (6) 30 Meter Sprint (photo-gate) to assess Type IIx fiber capacity; (7) VO_2max (2.4 km Cooper Test run) to assess aerobic capacity and Type I fiber dominance; (8) B-mode ultrasound (7.5 MHz) to measure the thickness and CSA of m. flexor digitorum superficialis (forearm) and m. deltoid (shoulder) as proxies of muscle fiber hypertrophy; and (9) Surface EMG on the radialis carpi flexor and anterior deltoid m. during standardized throwing tasks, to measure the amplitude and coherence of neuromuscular activation.

Data Analysis

Data were analyzed using IBM SPSS Statistics version 27. The normality test used Shapiro-Wilk. Pre-post comparisons in each group used paired samples t-test. Comparison of gain scores between the three category groups using one-way ANOVA and post-hoc Bonferroni. The effect of gender was studied using independent samples t-test on gain scores. Significance level $\alpha = 0.05$. The magnitude of the effect was reported as Cohen's d (paired) and partial eta-squared (η^2p) for ANOVA.

RESULTS AND DISCUSSION

Initial Characteristics of Samples

Table 1 presents the demographic characteristics and initial performance of the entire sample by competition category. There were no significant differences between groups on the performance variable ($p > 0.05$), confirming the homogeneity of the initial condition.

Table 1. Initial Characteristics of Sample of Petanque Soppeng Athletes (Pre-test)

Variabel	Goals (n=12) Mean±SD	Tir (n=12) Mean±SD	Mele (n=12) Mean±SD	p-value
Age (years)	22,4±3,1	22,8±2,9	22,1±3,3	0,849
Height (cm)	163,8±6,4	165,2±7,1	164,5±6,8	0,862
Body Weight (kg)	60,4±8,2	61,8±8,6	60,9±8,1	0,911
IMT (kg/m²)	22,5±2,4	22,7±2,6	22,6±2,3	0,975
Length of Practice (years)	2,9±1,1	3,1±1,2	2,8±1,0	0,763
Handgrip (kg)	31,4±4,8	32,1±5,2	31,8±4,6	0,920
VO_2max (ml/kg/min)	36,8±4,2	36,4±4,0	36,6±4,4	0,963
CSA Flexor Dig. (cm²)	2,84±0,38	2,91±0,42	2,87±0,40	0,882
CSA M. Deltoid (cm²)	8,42±1,12	8,68±1,18	8,54±1,15	0,803

Description: BMI = Body Mass Index; CSA = Cross-Sectional Area; SD = Standard Deviation; There was no significant difference between groups ($p > 0.05$)

Changes in Muscle Fiber Composition Indicators: Buts Group

Table 2 presents the change in the main variables in the Buts group after 12 weeks of a structured precision training program. This group showed the most dominant improvement in indicators reflecting Type I fiber characteristics and neuromuscular precision.

Table 2. Change in Muscle Fiber Composition Indicators of Buts Group (n=12)

Variable	Pre-test Mean±SD	Post-test Mean±SD	D (%)	p-value (d)
Handgrip (kg)	31,4±4,8	37,2±5,1	+18,4%	0,001* (1,18)
Wrist Flexor Endurance (rep)	42,6±6,4	55,9±7,2	+31,2%	0,001* (1,96)
One-Leg Stance – open eyes (sec)	24,8±4,2	35,3±5,1	+42,3%	0,001* (2,24)
One-Leg Stance – eyes closed (sec)	8,4±2,1	14,2±2,8	+69,0%	0,001* (2,31)
Shoulder Rotator Endurance (rep)	28,4±4,8	36,6±5,4	+28,9%	0,001* (1,60)
Shoulder Explosive Power (m)	4,82±0,58	5,42±0,64	+12,4%	0,001* (0,97)
VO_2max (ml/kg/min)	36,8±4,2	42,6±4,8	+15,8%	0,001* (1,28)
EMG Amplitudo FCR (mV)	0,44±0,08	0,52±0,09	+18,2%	0,001* (0,94)
CSA Flexor Dig. (cm^2)	2,84±0,38	3,08±0,41	+8,5%	0,004* (0,60)
Sprint 30m (s)	5,14±0,34	4,98±0,31	-3,1%	0,041* (0,49)

Keterangan: * signifikan (p<0,05); FCR = m. flexor carpi radialis; Δ = perubahan relatif; nilai negatif sprint = lebih cepat; d = Cohen's d

Changes in Muscle Fiber Composition Indicators: Tir Group

Table 3 presents the changes in the main variables in the Tir group. This group showed the greatest improvement in indicators of shoulder explosive strength and speed, reflecting the predominant adaptation of Type II fibers.

Table 3. Change in Muscle Fiber Composition Indicators of Tir Group (n=12)

Variable	Pre-test Mean±SD	Post-test Mean±SD	D (%)	p-value (d)
Handgrip (kg)	32,1±5,2	38,6±5,6	+20,2%	0,001* (1,21)
Shoulder Explosive Power (m)	4,86±0,62	6,06±0,72	+24,6%	0,001* (1,78)
1RM Shoulder Press (kg)	38,4±6,2	47,8±7,1	+24,5%	0,001* (1,43)
CSA M. Deltoid (cm^2)	8,68±1,18	10,62±1,34	+22,3%	0,001* (1,54)
Sprint 30m (s)	5,10±0,32	4,75±0,28	-6,8%	0,001* (1,16)
Wrist Flexor Endurance (rep)	41,8±6,2	51,4±7,1	+23,0%	0,001* (1,44)
One-Leg Stance – open eyes (sec)	25,2±4,4	31,8±5,2	+26,2%	0,001* (1,38)
VO_2max (ml/kg/min)	36,4±4,0	40,8±4,4	+12,1%	0,001* (1,05)
EMG Amplitudo Deltoid (mV)	0,58±0,10	0,76±0,12	+31,0%	0,001* (1,62)
CSA Flexor Dig. (cm^2)	2,91±0,42	3,28±0,48	+12,7%	0,001* (0,82)

Description: * significant (p<0.05); Δ = relative change; negative value of sprint = faster; d = Cohen's d

Changes in Muscle Fiber Composition Indicators: Mele Group

Table 4 presents the changes in the main variables in the Mele group undergoing a combined precision and explosive power training program. This group showed the most balanced and evenly distributed adaptation profiles across the domains measured.

Table 4. Changes in Muscle Fiber Composition Indicators of Mele Group (n=12)

Variable	Pre-test Mean±SD	Post-test Mean±SD	D (%)	p-value (d)
Handgrip (kg)	31,8±4,6	38,2±5,1	+20,1%	0,001* (1,34)
Wrist Flexor Endurance (rep)	42,2±6,1	54,8±7,0	+29,9%	0,001* (1,92)
One-Leg Stance – open eyes (sec)	24,6±4,0	33,2±4,8	+34,9%	0,001* (1,93)
Shoulder Explosive Power (m)	4,84±0,60	5,82±0,70	+20,2%	0,001* (1,49)
Shoulder Rotator Endurance (rep)	28,8±4,9	36,1±5,6	+25,3%	0,001* (1,39)
VO_2max (ml/kg/min)	36,6±4,4	42,2±4,9	+15,3%	0,001* (1,21)
Sprint 30m (s)	5,12±0,33	4,84±0,29	-5,5%	0,001* (0,90)
CSA Flexor Dig. (cm^2)	2,87±0,40	3,22±0,46	+12,2%	0,001* (0,82)
CSA M. Deltoid (cm^2)	8,54±1,15	10,04±1,28	+17,6%	0,001* (1,23)
EMG Amplitudo FCR (mV)	0,46±0,09	0,58±0,10	+26,1%	0,001* (1,27)

Keterangan: * signifikan (p<0,05); FCR = m. flexor carpi radialis; Δ = perubahan relatif; nilai negatif sprint = lebih cepat; d = Cohen's d

Comparison of Gain Scores Between Categories

Table 5 presents the results of a comparison of the gain scores between the three competition categories using a one-way ANOVA to identify variables that show statistically significant category-specific adaptation patterns.

Table 5. Comparison of Gain Scores Between Competition Categories (One-Way ANOVA)

Variabel	Buts Δ	Tir Δ	Mele Δ	F	p / η^2p
Handgrip (kg)	+5,8	+6,5	+6,4	0,82	0,450 / 0,05
Wrist Flexor Endurance (rep)	+13,3*	+9,6	+12,6	4,28	0,022* / 0,21
One-Leg Stance mata terbuka (detik)	+10,5*	+6,6	+8,6	5,64	0,008* / 0,26
One-Leg Stance mata tertutup (detik)	+5,8*	+3,4	+4,2	6,91	0,003* / 0,29
Shoulder Explosive Power (m)	+0,60	+1,20*	+0,98	7,42	0,002* / 0,31
CSA M. Deltoid (cm^2)	+0,82	+1,94*	+1,50	8,13	0,001* / 0,33
Sprint 30m (Δ detik)	-0,16	-0,35*	-0,28	5,02	0,013* / 0,23
VO_2max (ml/kg/min)	+5,8*	+4,4	+5,6	3,66	0,037* / 0,18
CSA Flexor Dig. (cm^2)	+0,24	+0,37	+0,35	2,14	0,134 / 0,11

Remarks: * the group with the highest gain score differed significantly in post-hoc Bonferroni (p<0.05); η^2p = partial eta-squared; Δ = absolute gain score

Exercise Basics and Dominance of Type I Fiber Adaptation

The most dramatic improvement in the Buts group was found in the postural stability variables (one-leg stance open eye +42.3%; closed eye +69.0%) and wrist flexor endurance (+31.2%). These two indicators are physiologically strong representations of the dominance of Type I (slow-twitch, oxidative) fibers. Type I fibers are characterized by high mitochondrial density, superior activity of oxidative enzymes (citrate synthase, succinate dehydrogenase), and outstanding fatigue resistance due to their ability to efficiently produce ATP through oxidative phosphorylation over a long period of time (Schiaffino & Reggiani, 2011).

The very large postural stability adaptation in the Buts group (effect size d = 2.24–2.31, included in the 'very large' category) reflects an increase not only in Type I postural muscle fibers, but more fundamentally in the proprioceptive system and cortical neuromuscular control. Repeated precision drills performed 200–400 times per training session induce adaptation at the central nervous system level through the long-term potentiation (LTP) mechanism in the corticospinal motor circuit, resulting in an increase in forward model accuracy and a decrease in motor variability which is a hallmark of experienced petanque athletes (Crespo et al., 2019).

The 15.8% increase in VO_2max in the Buts group although not the primary goal of their exercise program reflects the positive impact of the combined aerobic exercise component and the volume of high-technique exercises that indirectly increase cardiorespiratory capacity through the accumulation of energy expenditure. These findings are consistent with the hypothesis that exercise involving high volumes of Type I fiber contractions (repetitive, submaximal) gradually induces mitochondrial biogenesis through the PGC-1α pathway, even without explicit aerobic sessions (Zhang et al., 2024).

Tir Training and Dominance of Type II Fiber Adaptation

The Tir group showed the largest increase in the shoulder explosive power variables (Shoulder Explosive Power +24.6%; d = 1.78), 1RM shoulder press (+24.5%; d = 1.43), CSA m. deltoid (+22.3%; d = 1.54), and 30m sprint (-6.8%; d = 1.16). This adaptation profile is highly consistent with the increased characteristics of Type IIa fibers—fast oxidative glycolytic—which are the most responsive type to submaximal-to-maximum explosive force training (Jessen et al., 2026).

The mechanism of Type II fiber hypertrophy in the Tir group was mediated by the mTORC1 pathway activated by high mechanical stress during explosive overhead throw and shoulder press exercises. The activation of mTORC1 phosphorylates the downstream targets p70S6K1 and 4E-BP1, which collectively increase the synthesis of myofibrillar proteins specifically the MHC-IIa (MYH2) isoform resulting in an increase in CSA Type II fibers detected by ultrasonography. The 31.0% increase in deltoid EMG amplitude in the Tir group reflects an increase in simultaneous neural drive and more and synchronized motor recruitment of units, which are signs of the neuromuscular adaptations that accompany hypertrophy (Folland & Williams, 2007).

Mele Group as a Concurrent Fiber Adaptation Model

The most balanced adaptation profile of the Mele group with substantial improvements in almost all variables without a marked advantage in a single domain reflects the characteristics of concurrent training assigned to this versatile position. Mele exercises that combine high-volume precision drills with explosive strength training create a stimulus that recruits a broad spectrum of muscle fibers: from Type I for endurance and postural components, to Type IIa and IIx for strength and speed components.

Interestingly, the Mele group showed an increase in CSA m. deltoid (+17.6%) which was between Buts (+not dominant in deltoid) and Tir (+22.3%), as well as an increase in one-leg stance (+34.9%) which was between Buts (+42.3%) and Tir (+26.2%). This graduation pattern not only demonstrates the success of the training program in producing adaptations that are proportional to the stimulus, but also confirms the validity of the position-specific training program design applied in this study.

Differences in Adaptation Based on Gender

Separate analysis by gender in the study this suggests that male athletes generally record greater gain scores on the strength and hypertrophy variables (CSA m. deltoid: male-laki +20,8 ± 3.2% vs women +14.6 ± 2.8%; p = 0.003), while there was no significant difference in the variables of postural stability (males +40.1 ± 6.4% vs females +42.8 ± 6.8%; p = 0.412) and muscle endurance (p = 0.284). This difference in the strength-hypertrophy variable is explained by physiologically higher testosterone levels in males, which amplify the anabolic signaling of the mTORC1 pathway after strength training (Kraemer & Ratamess, 2004). Adaptation equivalence on the variables of postural stability and endurance showed that the plasticity of Type I fibers was not significantly dependent on sex hormone levels, and was primarily mediated by the PGC-1α pathway that is responsive to the volume and frequency of oxidative contractions.

Table 6. Muscle Fiber Composition Profile and Recommendations for Petanque Category-Based Training Programs

Aspects	Goals (Point)	Shooting	Mele (All-Rounder)
Fiber Dominance	Type I (slow-twitch) + Type IIa	Type IIa & IIx (fast-twitch dominant)	Type IIa hybrid (balanced I & II)
Key Adaptations	Proprioception, postural stability, flexor endurance	Deltoid hypertrophy, explosive force of the shoulder	Balanced strength + endurance
Molecular Pathways	PGC-1α+ proprioseptif (LTP cortical)	Dominant mTORC1 + high EMG drive	PGC-1α + mTOR simultaneous
Primary Training Methods	Repetitive precision drill (200-400 throws/session) + balance & proprioception	Explosive overhead training + plyometrik lengan + sprint interval	Concurrent: precision + strength + aerobic
Key Parameters	High volume; submaximal intensity; Minimal rest	Intensity 80-95% max; low-medium volume; rest 2-3 minutes	Periodization of blocks; Alternating Method Dominance Per Phase
Indicator Monitoring	One-leg stance; handgrip; wrist endurance; Field precision score	Medicine ball throw; 1RM shoulder press; CSA ultrasound	All of the above indicators + VO_2max

Keterangan: LTP = Long-Term Potentiation; CSA = Cross-Sectional Area; PGC-1α = Peroxisome Proliferator-Activated Receptor Gamma Coactivator-1 Alpha

CONCLUSIONS AND SUGGESTIONS

Conclusion

This research produces four main conclusions that have important implications for the development of petanque coaching science and practice in Soppeng and on a national scale.

First, a 12-week structured petanque training program was shown to significantly alter the muscle fiber-type composition indicators in 36 Soppeng petanque athletes. All measured variables showed a statistically significant increase ($p < 0.05$) by a large effect magnitude (Cohen's $d > 1.0$ in the majority of variables), confirming the effectiveness of the periodized exercise program in inducing neuromuscular and morphological adaptation of muscles even over a 12-week time span.

Second, the pattern of changes in the composition of muscle fiber types is category-specific. The Buts group showed adaptations dominated by Type I fiber characteristics i.e., increased flexor fiber endurance (+31.2%), postural stability (+42.3% open eyes; +69.0% closed eyes), and aerobic capacity (+15.8%) reflecting PGC-1α pathway activation and cortical adaptation through repeated precision drills. The Tir group showed adaptations that reflect hypertrophy and Type II fiber recruitment, especially in the CSA m. deltoid (+22.3%), shoulder

explosive strength (+24.6%), and sprint velocity (-6.8%), mediated by the mTORC1 pathway. The Mele group showed the most balanced adaptation profile, reflecting concurrent fiber adaptation.

Third, the difference in gain scores between categories was shown to be statistically significant in the key variable ($p = 0.001–0.037$; $\eta^2p = 0.18–0.33$ / medium-large effect), providing a strong scientific basis untuk penerapan program latihan yang terdiferensiasi berdasarkan kategori kompetisi dalam pembinaan atlet petanque.

Fourth, male athletes showed adaptive excellence in the strength-hypertrophy variable, while there were no significant differences in the variables of postural stability and muscle endurance, indicating that Type I fiber adaptation is more gender-neutral than Type II fiber adaptation.

Suggestions

Based on the findings of this study, several suggestions were proposed: (1) Soppeng Regency petanque administrators and coaches are advised to adopt a category-specific training program designed based on the physiological profile and task demands of each competition category, using monitoring parameters and indicators that have been proven effective in this study; (2) Repeated precision drill programs with a minimum volume of 200 throws per session should be a mandatory component of the buts program, given the proprioceptive adaptation and the enormous Type I fibers produced; (3) The tir training program is recommended to integrate shoulder explosive strength training (overhead throw, medicine ball, push press) with a progressive intensity periodization approach; (4) Follow-up research is recommended to conduct direct muscle biopsy analysis in petanque athletes to confirm the predicted MHC isoform shift, as well as to examine the effect of long-term periodization (>6 months) on the plasticity of muscle fibers of Indonesian petanque athletes; (5) The Soppeng Regency Government through the Youth and Sports Office is advised to support science-based coaching programs by providing portable ultrasound facilities and isokinetic dynamometers as a tool to monitor the physical condition of petanque athletes on a regular basis.

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