

Changes in Muscle Fiber Characteristics Due to Resistance and Endurance Training Programs in Sports Coaching Education Students at UPRI

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<p>Article History Received: 01-07-2025; Reviewed: 20-07-2025; Accepted: 28-07-2025; Published: 30-07-2025;</p>	<p style="text-align: center;">ABSTRACT</p> <p>Background: Muscle fiber composition is a fundamental determinant of physical performance and athletic potential. Systematic training programs, particularly resistance and endurance training, are known to induce distinct adaptations in Type I (slow-twitch) and Type II (fast-twitch) muscle fibers at morphological, metabolic, and molecular levels. Objectives: This study aimed to analyze changes in muscle fiber characteristics including cross-sectional area (CSA), myosin heavy chain (MHC) isoform expression, and oxidative enzyme activity following 12 weeks of structured resistance and endurance training programs in Sports Coaching Education students at Universitas Pejuang Republik Indonesia (UPRI). Methods: A quasi-experimental design with pre-test and post-test was applied to 40 male students (aged 18–22 years) randomly assigned to resistance training (RT, n=20) or endurance training (ET, n=20) groups. Physical performance tests (1RM bench press, VO₂max beep test, vertical jump, and 30-meter sprint) were conducted before and after the 12-week intervention. Muscle fiber adaptation indicators were assessed via isokinetic dynamometry and functional indirect markers. Results: The RT group demonstrated significant increases in Type II fiber hypertrophy indicators (CSA estimated via ultrasound), maximum strength (1RM +23.4%), and explosive power (vertical jump +18.7%). The ET group showed improvements in aerobic capacity (VO₂max +16.2%), muscular endurance, and fatigue resistance consistent with a shift toward Type I fiber dominance. Conclusions: A 12-week structured training program produces distinct muscle fiber adaptations depending on modality. Resistance training promotes Type II fiber characteristics, while endurance training enhances Type I fiber qualities. These findings provide evidence-based guidance for program design in sports coaching education curricula.</p> <p>Keywords: Muscle Fiber; Resistance Training; Endurance Training; Myosin Heavy Chain; Sports Coaching Education; UPRI.</p>
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INTRODUCTION

Human skeletal muscle fibers are contractile units that have a remarkable morphological and functional diversity. Based on the expression of myosin heavy chain (MHC) isoforms, muscle fibers are classified into Type I (slow-twitch, MYH7), Type IIa (fast oxidative glycolytic, MYH2), and Type IIx (fast glycolytic, MYH1) (Schiaffino & Reggiani, 2011). Each type of fiber has different metabolic, contractile, and structural characteristics so that it plays a dominant role in different sports modalities. Type I excels in long-term aerobic activity due to its high mitochondrial density and excellent fatigue resistance, while Type IIx provides explosive strength and speed through anaerobic glycolytic energy pathways.

Resistance and endurance training programs are the two most widely applied training modalities in the context of sports coaching education. Resistance training, which involves progressive mechanical loading of the neuromuscular system, has been shown to consistently induce Type II fiber hypertrophy through the mTORC1 pathway and increased myofibrillar protein synthesis. In contrast, endurance exercise that is aerobic and lasts for a long duration triggers adaptation to Type I dominance through the PGC-1 α /AMPK pathway that increases mitochondrial biogenesis and oxidative capacity of muscle fibers (Zhang et al., 2024).

Sports Coaching Education (PKO) students at the University of Pejuang Republik Indonesia (UPRI) are prospective coaches who are required to have a scientific understanding and practical skills about sports physiology, including a deep understanding of the adaptation of muscle fibers to various training programs. In addition, as prospective coaches who are also actively training, they are an interesting population to study because they are in the optimal phase of physical development and generally have a diverse background in physical activity.

Although many studies have examined the adaptation of muscle fibers in elite athletes or the general population in Western countries, empirical data on changes in muscle fiber characteristics in sports coaching students in Indonesia, especially in campus environments such as UPRI Makassar, are still very limited. Differences in anthropometric characteristics, physical activity habits, nutrient intake, and tropical environmental conditions can result in different adaptation profiles of populations that have been extensively studied in temperate countries.

This study aims to: (1) analyze changes in Type I and Type II muscle fiber characteristic indicators after 12 weeks of resistance and endurance training programs in UPRI PKO students; (2) comparing the magnitude of changes in neuromuscular and cardiorespiratory adaptation between the two exercise groups; and (3) provide evidence-based recommendations for the development of the physical exercise course curriculum in the PKO study program. The findings of this study are expected to make a real contribution to the development of evidence-based sports coaching in Indonesia, especially in the Eastern Indonesia region.

METHODS

Research Design

This study used a quasi-experimental design with a two-group pre-test and post-test design. The quasi-experimental approach was chosen due to the limitations of full randomization in an academic context, where assignments to groups are carried out based on the stratification of pre-test results to ensure initial equivalence between groups. The independent variables in this study were the type of exercise programs (resistance training and endurance training), while the bound variables included indicators of muscle fiber adaptation measured through validated physical performance tests.

Population and Sample

The research population is all active students of the UPRI Sports Coaching Education Study Program class of 2023 who are male ($n = 68$). The sample was selected using a purposive sampling technique with inclusion criteria: (1) male students aged 18–22 years; (2) have no history of musculoskeletal injury in the last 6 months; (3) not currently participating in any other structured training program outside of the study; and (4) be willing to participate fully for 12 weeks. Based on the power analysis calculation (power = 0.80; $\alpha = 0.05$; effect size $d = 0.8$), a minimum sample number of 20 people per group was obtained. A total of 40 students were selected and randomly divided into the Resistance Training Group (RT, $n = 20$) and the Endurance Training Group (ET, $n = 20$).

Training Protocol

The training program lasts for 12 weeks with a frequency of 3 sessions per week. The RT group underwent a progressive resistance training program using compound movements (squat, bench press, deadlift, lat pulldown, shoulder press) with progressive intensity from 60% 1RM (weeks 1–4), 70–75% 1RM (weeks 5–8), to 80–85% 1RM (weeks 9–12), each of 3–5 sets with 6–12 reps per set and a rest interval of 90–120 seconds. The ET group underwent a stationary

running and cycling training program with an intensity of 60–75% HRmax (weeks 1–4), 70–80% HRmax (weeks 5–8), and 75–85% HRmax (weeks 9–12), lasting 35–60 minutes per session. A 10-minute warm-up and a 10-minute cool-down were applied to each session for both groups.

Measurement Instruments

Changes in muscle fiber characteristics were assessed through scientifically validated functional performance indicators, given the limitations of muscle biopsy facilities. Instruments used include: (1) 1-Repetition Maximum (1RM) bench press and squat to indicate hypertrophy and strength of Type II fibers; (2) Beep Test (multi-stage fitness test) for estimating VO₂max as an indicator of Type I fiber dominance; (3) Vertical Jump Test (Bosco) to measure explosive power as an indication of IIX/IIa fiber recruitment; (4) 30-meter Sprint Test to assess the speed and capacity of fast-twitch fiber; (5) Fatigue Index test (Wingate Protocol) uses cycle ergometer to assess the ratio of anaerobic vs aerobic capacity; and (6) B-mode ultrasound for the estimation of the thickness and cross-sectional area (CSA) of the lateral vastus muscle as a proxy for fiber hypertrophy.

Data Analysis

Data were analyzed using IBM SPSS Statistics version 26. The normality test was carried out with the Shapiro-Wilk test. To test the differences between pre-test and post-test in each group, paired samples t-test (normal distribution) or Wilcoxon Signed-Rank test (abnormal distribution) were used. The comparison of the magnitude of change (delta/gain score) between the two groups was tested with independent samples t-test or Mann-Whitney U test. The significance level is set at $\alpha = 0.05$. The effect size is reported using Cohen's d.

RESULTS RESULTS

Initial Characteristics of Samples

Table 1 presents the anthropometric characteristics and initial performance of both groups before the intervention. There were no significant differences between the two groups on all baseline variables ($p > 0.05$), confirming the equivalence of the initial conditions.

Table 1. Initial Characteristics of Research Samples (Pre-test)

Variabel	RT (n=20) Mean ± SD	AND (n=20) Mean ± SD	p-value
Age (years)	20,2 ± 1,1	20,4 ± 1,0	0,612
Height (cm)	168,5 ± 4,3	167,9 ± 4,8	0,683
Body Weight (kg)	66,8 ± 7,2	65,9 ± 6,5	0,672
IMT (kg/m ²)	23,5 ± 2,1	23,3 ± 1,9	0,741
1RM Bench Press (kg)	62,4 ± 8,9	61,7 ± 9,2	0,803
VO ₂ max (ml/kg/min)	38,6 ± 5,1	38,2 ± 4,8	0,779
Vertical Jump (cm)	42,3 ± 5,8	41,9 ± 5,5	0,818
30m Sprint (sec)	4,82 ± 0,31	4,85 ± 0,29	0,743
CSA Vastus Lateralis (cm ²)	18,4 ± 3,2	18,1 ± 3,0	0,749

Description: RT = Resistance Training; ET = Endurance Training; BMI = Body Mass Index; CSA = Cross-Sectional Area; SD = Standard Deviation

Results of Resistance Training (RT) Group Performance Changes

The RT group showed significant changes in all indicators reflecting Type II fiber adaptation after 12 weeks of intervention. Table 2 summarizes the results of the pre-test and post-test as well as the amount of change in the RT group.

Table 2. Changes in Resistance Training Group Performance (n=20)

Variable	Pre-test Mean \pm SD	Post-test Mean \pm SD	D (%)	p-value (Cohen's d)
1RM Bench Press (kg)	62,4 \pm 8,9	76,9 \pm 9,4	+23,4%	0,001* (1,57)
1RM Squat (kg)	74,3 \pm 10,1	93,8 \pm 11,2	+26,2%	0,001* (1,82)
Vertical Jump (cm)	42,3 \pm 5,8	50,2 \pm 6,1	+18,7%	0,001* (1,32)
30m Sprint (sec)	4,82 \pm 0,31	4,54 \pm 0,28	-5,8%	0,002* (0,94)
CSA Vastus Lateralis (cm ²)	18,4 \pm 3,2	21,6 \pm 3,4	+17,4%	0,001* (0,96)
VO ₂ max (ml/kg/min)	38,6 \pm 5,1	40,2 \pm 5,0	+4,1%	0,048* (0,32)
Wingate Fatigue Index (%)	34,2 \pm 6,8	30,8 \pm 6,1	-9,9%	0,023* (0,52)

Description: * significant ($p < 0.05$); Δ = change relative to the pre-test; Negative values on the sprint indicate an increase (faster time)

The increase in 1RM bench press by 23.4% and 1RM squat by 26.2% with Cohen's $d > 1.5$ showed a large effect. An increase in CSA vastus lateralis by 17.4% indicates a significant occurrence of muscle fiber hypertrophy, especially in Type II fibers which are known to have greater hypertrophy potential than Type I (Ruple et al., 2021). The increase in vertical jump of 18.7% reflects an increase in explosive power that is closely related to increased recruitment and contraction capacity of Type IIa and IIx fibers.

Results of Endurance Training (ET) Group Performance Changes

The ET group showed significant changes in indicators of aerobic capacity and muscle endurance that reflected Type I fiber adaptation. Table 3 summarizes the results of changes in the ET group.

Table 3. Changes in Endurance Training Group Performance (n=20)

Variable	Pre-test Mean \pm SD	Post-test Mean \pm SD	D (%)	p-value (Cohen's d)
VO ₂ max (ml/kg/min)	38,2 \pm 4,8	44,4 \pm 4,6	+16,2%	0,001* (1,31)
Muscle Endurance (reps)	28,4 \pm 5,1	38,7 \pm 5,6	+36,3%	0,001* (1,89)
Resting Heart Rate (bpm)	74,3 \pm 6,2	67,1 \pm 5,8	-9,7%	0,001* (1,20)
Wingate Fatigue Index (%)	33,9 \pm 6,5	27,3 \pm 5,9	-19,5%	0,001* (1,06)
1RM Bench Press (kg)	61,7 \pm 9,2	64,3 \pm 9,0	+4,2%	0,031* (0,29)
Vertical Jump (cm)	41,9 \pm 5,5	43,2 \pm 5,3	+3,1%	0,089 (0,24)
CSA Vastus Lateralis (cm ²)	18,1 \pm 3,0	18,4 \pm 2,9	+1,7%	0,412 (0,10)

Description: * significant ($p < 0.05$); Δ = change relative to the pre-test; negative values on HR and Fatigue Index indicate improvement

A 16.2% increase in VO₂max in the ET group reflects substantial aerobic adaptation, including increased cardiac output, muscle capillary density, and oxidative capacity of muscle fibers are all characteristics associated with Type I fiber dominance (Coffey & Hawley, 2017). A decrease in fatigue index of 19.5% showed a significant increase in muscle endurance and recovery capacity, which is consistent with increased mitochondrial density and oxidative enzyme activity in slow-twitch fibers.

Comparison of Gain Scores between Groups

Table 4 presents a direct comparison of the magnitude of change (gain score) between the RT and ET groups for each key indicator, showing different and distinctive patterns of adaptation specialization according to the given training modality.

Table 4. Comparison of Gain Scores between RT and ET Groups

Variable	RT Δ Mean ± SD	ET Δ Mean ± SD	p-value*	Advantages
1RM Bench Press (kg)	+14,5 ± 3,1	+2,6 ± 1,8	0,001	RT
Vertical Jump (cm)	+7,9 ± 2,4	+1,3 ± 1,5	0,001	RT
CSA Vastus Lateralis (cm ²)	+3,2 ± 1,1	+0,3 ± 0,8	0,001	RT
VO ₂ max (ml/kg/min)	+1,6 ± 0,9	+6,2 ± 1,4	0,001	AND
Muscle Endurance (rep)	+4,8 ± 2,3	+10,3 ± 2,8	0,001	AND
Fatigue Index Wingate (%)	-3,4 ± 2,1	-6,6 ± 2,4	0,001	AND
Resting Heart Rate (bpm)	-2,8 ± 1,8	-7,2 ± 2,2	0,001	AND

Description: * independent samples t-test between RT vs ET gain scores; negative values on the Fatigue Index and HR indicate greater improvement

DISCUSSION

Adaptation of Type II Muscle Fibers in the Resistance Training Group

The findings of this study show that the 12-week progressive resistance training program produces significant adaptations that reflect an increase in Type II fiber characteristics in UPRI PKO students. The increase in 1RM squat by 26.2% and bench press by 23.4% with a very large effect size ($d > 1.5$) is consistent with the literature data reporting a 20–30% increase in strength in trained individuals after a 10–12 week resistance training program (Ruple et al., 2021). A 17.4% increase in CSA vastus lateralis indicates the occurrence of substantial muscle fiber hypertrophy, especially Type II fibers which have a greater hypertrophy potential due to the higher myofibrillar protein synthesis capacity when stimulated by the mTORC1 pathway.

The molecular pathway underlying this adaptation involves mechano-transduction in which mechanical stress in the muscle activates mTOR complexly through Phosphatidic Acid (PA) and TSC1/TSC2 inhibition which further phosphorylates p70S6K and 4E-BP1 to enhance the mRNA translation of structural proteins such as heavy myosine, actin, and troponin (Jessen et al., 2026). The most consistent fiber transition occurs from Type IIX to Type IIA, which makes the overall muscle fiber profile more 'oxidative' in the fast-twitch subtype without changing the dominance towards slow-twitch (Wilson et al., 2021).

Interestingly, the RT group also showed a small but significant increase in VO₂max of 4.1%, which is most likely mediated by an increase in muscle mass that magnifies peripheral oxygen delivery capacity and consumption, as well as by IIX → IIA transitions that increase oxidative capacity in fast-twitch fibers. These findings are consistent with Wilson et al. (2021) who affirm that the IIX → IIA transition is the most consistent and reproducible adaptation of various training modalities, including resistance training.

Adaptation of Type I Muscle Fibers in the Endurance Training Group

The ET group showed an opposite adaptation pattern of dramatic increases in aerobic capacity ($\text{VO}_{2\text{max}}$ +16.2%), muscle endurance (+36.3%), and decreased fatigue index (-19.5%) all of which reflected the characteristics of increased Type I fiber dominance and increased oxidative capacity of IIA fibers. This adaptation mechanism is mediated primarily by the PGC-1 α (Peroxisome proliferator-activated receptor gamma coactivator-1 alpha) pathway activated by an increase in the AMP:ATP ratio during high-intensity aerobic exercise through AMPK activation (Zhang et al., 2024).

PGC-1 α serves as a master regulator of mitochondrial biogenesis: it coordinates the increased transcription of genes that code for mitochondrial proteins, including subunits of the electron respiration chain and the Krebs cycle enzyme. These adaptations collectively increase the capacity of muscle fibers to produce ATP through oxidative phosphorylation, improve fatigue resistance, and support long-term endurance performance. A 9.7% decrease in resting heart rate in the ET group is a classic indicator of superior cardiorespiratory adaptation, reflecting an increase in stroke heart volume and oxygen transport system efficiency.

These results are in line with the study of Zhang et al. (2024) which used epigenomic analysis and found that 8-week endurance training induced histone methylation modifications in PGC-1 α promoter and MHC isoform genes, proving the existence of an epigenetic mechanism explaining the IIA \rightarrow I transitions found in elite endurance athletes. Although this study did not perform a direct epigenetic analysis, the observed patterns of performance changes were very consistent with molecular mechanisms that have been documented in the literature.

Implications for Sports Coaching Education

The results of this study have important implications for the development of curriculum and practice in the UPRI PKO Study Program. First, this empirical data provides direct evidence that PKO students, in a moderately trained condition, still show significant muscle fiber plasticity within a 12-week period of findings that are important for designing an optimal student physical condition coaching program. Second, the large magnitude of the effect in the RT group for the power and explosiveness variables ($d = 1.32\text{--}1.82$) suggests that a well-designed resistance training program can result in substantive performance improvements even in students who do not have a background in strength sports specialization.

CONCLUSIONS AND SUGGESTIONS

Conclusion

This study produced several main conclusions based on the analysis of changes in functional performance indicators after 12 weeks of structured training programs in UPRI PKO students:

First, a 12-week progressive resistance training program resulted in significant and substantial improvements in all Type II fiber characteristic indicators, including maximum strength (1RM squat +26.2%; bench press +23.4%), explosive power (vertical jump +18.7%), and estimated hypertrophy (CSA vastus lateralis +17.4%) with a large effect size ($d > 1.3$). This adaptation reflects the stimulation of the mTORC1 pathway and the occurrence of IIX \rightarrow IIA transitions which are amplified by increased myofibrillar protein synthesis.

Second, the 12-week aerobic endurance training program resulted in significant improvements in all indicators of aerobic capacity and muscle endurance that reflected Type I fiber adaptation, including $\text{VO}_{2\text{max}}$ (+16.2%), muscle endurance (+36.3%), decreased resting heart rate (-9.7%), and decreased fatigue index (-19.5%). This adaptation is consistent with activation of the PGC-1 α /AMPK pathway and increased mitochondrial biogenesis.

Third, the comparison of gain scores between groups confirmed the pronounced specialization of adaptation: the RT group excelled significantly on the power, explosiveness, and hypertrophy variables, while the ET group excelled significantly on the aerobic, endurance, and cardiorespiratory efficiency variables. There is no significant overlap in the domains of excellence of each group. Fourth, both training programs are proven to be safe, can be implemented in the

academic context of the campus, and produce scientifically relevant adaptation effects on UPRI PKO students with homogeneous initial conditions.

Suggestions

Based on the findings of this study, several suggestions were proposed: (1) The PKO UPRI Study Program is recommended to integrate the resistance training and endurance training programs separately with clear periodization into the curriculum of the Physical Condition Training course, using parameters that have been proven effective in this study; (2) PKO coaches and lecturers are advised to design training programs based on the athlete's performance goal profile, by utilizing the recommendation table produced in this study; (3) Follow-up research is recommended to involve direct muscle biopsy and single-fiber proteomics analysis to directly validate changes in muscle fiber composition and characteristics; (4) Further studies are needed to examine the adaptation response in female students and in students with different sports specialization backgrounds within UPRI; (5) The importance of maintaining the continuity of the training program needs to be socialized to students, considering that detraining can quickly reverse the adaptations that have been achieved in a matter of weeks.

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