Changes in blood lactate levels at sedentary adolescent boys after asian squat exercise

Cambios en los niveles de lactato en sangre en adolescentes sedentarios después del ejercicio de sentadilla asiática

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Abstract

Introduction: Sedentary behavior in adolescents has been linked to adverse health outcomes. Asian squat exercises, a form of low-intensity resistance training, offer the advantage of accessibility and short duration.
Objective: to investigate the impact of Asian squat training on blood lactate levels in sedentary adolescent boys.
Methodology: A total of 24 participants, aged 15-17, were divided into a control group and a treatment group, with the latter performing Asian squats three times weekly for eight weeks.
Results: There was no significant difference ($p = 0.093$) in baseline lactate values of week 0 and 8 in the treatment group. Post Asian squat training from week 1 to week 4 ($p = 0.602$) and week 1 to week 8 ($p = 0.087$), changes in lactate levels were not significant. However, from week 4 to week 8, there was a significant change ($p = 0.004$). There was no significant difference in changes in lactate levels at week 1, 4, and 8 (F 3.161 and $p = 0.062$).
Discussion: In the treatment group, lactate levels increased by 3.73 mmol/l at week 1 and 4.56 mmol/l at week 8. Neither change was statistically significant, but the increase was greater effect on the change at week 8 compared to week 1.
Conclusions: There was an increase in blood lactate levels after Asian squat training for 8 weeks, and there were differences in changes in blood lactate levels between the two groups. Asian squat training is a simple, safe, and easy to do resistance training.

Keywords

Sedentary; Asian squat; blood lactate levels.

Resumen

Introducción: El comportamiento sedentario en adolescentes está asociado con riesgos para la salud, mientras que las sentadillas asiáticas, como ejercicio de resistencia de baja intensidad, son una opción accesible y de corta duración para contrarrestar estos efectos.
Objetivo: Investigar el impacto del entrenamiento con sentadillas asiáticas en los niveles de lactato en sangre en adolescentes varones sedentarios.
Metodología: Un total de 24 participantes, de 15 a 17 años, fueron asignados a un grupo de control y un grupo de tratamiento. Este último realizó sentadillas asiáticas tres veces por semana durante ocho semanas.
Resultados: No se observaron diferencias significativas en los niveles de lactato basal entre las semanas cero y ocho ($p = 0.093$) en el grupo de tratamiento. Los cambios en los niveles de lactato entre las semanas uno y cuatro ($p = 0.602$) y entre las semanas uno y ocho ($p = 0.087$) tampoco fueron significativos. Sin embargo, se evidenció un cambio significativo entre las semanas cuatro y ocho ($p = 0.004$). En general, no se encontraron diferencias significativas en los niveles de lactato entre las semanas uno, cuatro y ocho ($F = 3.161$, $p = 0.062$).
Discusión: En el grupo de tratamiento, los niveles de lactato aumentaron de 3.73 mmol/l en la semana 1 a 4.56 mmol/l en la semana 8, mostrando un incremento mayor en la semana 8, aunque sin significancia estadística.
Conclusiones: Hubo un aumento en los niveles de lactato en sangre después de ocho semanas de entrenamiento con sentadillas asiáticas, y se observaron diferencias en los cambios de los niveles de lactato entre los dos grupos

Palabras clave

Sedentario; sentadillas asiáticas; niveles de lactato en sangre.

Introduction

Sedentary behavior characterized by prolonged periods of sitting or lying down for activities such as gaming, watching TV, or reading, is associated with numerous health risks in children and adolescents. These include obesity, poor metabolic health, reduced physical fitness, social isolation, and disrupted sleep patterns. Additionally, sedentary lifestyles contribute to fatigue by decreasing muscle mass and strength. Engaging in regular physical activity, particularly aerobic and resistance exercises, has been shown to improve muscle endurance and overall fitness (Fyfe et al., 2022).

The clinical significance of addressing sedentary behaviour in adolescents cannot be overstated. As this age group is particularly vulnerable to the negative health impacts of inactivity, understanding effective interventions is crucial for promoting long-term health and preventing chronic diseases. The squat is an essential exercise for teenagers and young adults as prehabilitation before intense physical activities or sports. Their effectiveness depends on how they are performed, affecting both biomechanics and neuromuscular functions. The squat is a fundamental exercise in resistance training, known for its ability to strengthen the lower limbs and improve knee movement control (Vargas-Molina et al., 2022).

This study specifically focuses on the Asian squat, a vital exercise for teenagers and young adults that serves as prehabilitation prior to engaging in strenuous physical activities or sports. Among the various squat variations, the Asian squat—also referred to as the Bodyweight Deep Squat or Flat Foot Squat—was chosen for this study due to its unique benefits and cultural significance (Ganokroj et al., 2021). According to Hoa (2022), the benefits of Asian squats include increased ankle mobility, allowing for deeper knee flexion and lower head height, which produces a more stable posture and requires greater torque on the knee joints than other types of squats. Unlike other squat variations, the Asian squat promotes greater flexibility in the hips, knees, and ankles, which is crucial for developing proper movement patterns and preventing injuries. Furthermore, it is a functional movement commonly utilized in daily life across many Asian cultures, rendering it more relatable and accessible for adolescents (Kothurkar et al., 2023). Exercises based on body mass, like the Asian squat, which was used in earlier research, have a number of benefits. One of these is that they can be performed by a wide range of people in a short amount of time (around 15 minutes), anyplace (Ogawa et al., 2023).This accessibility makes the Asian squat an ideal choice for promoting physical activity among adolescents, particularly in the context of combating the adverse effects of sedentary lifestyles.

Blood lactate levels (BLa) are a key factor in assessing the intensity and effectiveness of exercise, commonly used to gauge metabolic responses during physical activity (Yui et al., 2021). Historically, research has shown that lactate is not merely a waste product but plays a crucial role in energy production, particularly during high-intensity exercise. An increase in BLa can signal hypoxemia or ischemia, but it is also a normal physiological response to exercise. During high-intensity activities, several factors contribute to the rise in lactate levels. An increased glycolytic rate, which occurs when the body relies more on anaerobic metabolism for energy, leads to greater lactate production. Additionally, lower intramuscular oxygen tension during intense exercise limits the capacity for aerobic metabolism, further elevating lactate levels (Sadowski et al., 2024). Elevated lactate levels may indicate an increased reliance on glycolysis, which could serve as a potential biomarker for identifying individuals at risk for metabolic diseases (In het Panhuis et al., 2022).

In strength training and high-intensity activities, BLa levels typically rise significantly—up to ten times resting levels—during and after intense resistance or sprint training. This elevation in lactate is indicative of the body's metabolic response to the stress of exercise, reflecting the balance between lactate production and clearance (Sadowski et al., 2024). A study by Walker et al. (2022), the impact of rest interval length between sets on neuromuscular performance and metabolic responses during strength training was examined. The study found that blood lactate levels rose nearly equally over three training sessions, with no discernible changes in muscle activity following multiple sets, irrespective of rest interval length. Research by Fairuz Silvi et al. (2022), showed that high-intensity training with Nintendo Switch™ "Fitness Boxing 2" resulted in increased BLa and VO2max levels in young, healthy men who were not athletes. The training intensity was noted to exceed 15% of one-repetition maximum (1RM), with 10 repetitions and a one-minute rest interval.

The connection between sedentary behavior, Asian squats, and blood lactate is crucial for understanding the potential health benefits of this exercise. Sedentary lifestyles contribute to poor metabolic health, and exercises like the Asian squat may help mitigate these effects by improving metabolic responses, as indicated by changes in BLa levels. However, there is a research gap regarding how Asian squat training specifically impacts blood lactate levels in inactive adolescents, as most studies have focused on other types of exercise. This study aims to explore how Asian squat training affects blood lactate levels in inactive male teenagers, providing insights into the physiological benefits of these activities for adolescents. Understanding these metabolic responses will offer a clearer picture of the exercise's impact on adolescent health, particularly in addressing the metabolic consequences of a sedentary lifestyle.

Method

Study Design and Approach

This study employed a two-group, randomized, single-blind controlled trial design with a pre-test and post-test approach. The objective was to investigate the effects of an 8-week Asian squat exercise intervention on blood lactate levels and VO2max in sedentary male adolescents. A randomized controlled trial (RCT) design was selected to minimize bias and ensure robust results through random assignment of participants to either the treatment or control group.

Ethical Approval

Ethical approval for the study was granted by the Health Research Ethics Commission of Dr. Soetomo General Hospital Surabaya (ethical feasibility number 0993/LOE/301.4.2/VIII/2022). Informed consent was obtained from all participants and their legal guardians prior to inclusion in the study.

Samples and Subjects

The sample size of 24 participants was determined using an a priori power analysis, based on an estimated effect size (Cohen's d = 0.5) with 80% power and a 5% alpha level. This calculation indicated that 12 participants per group would be sufficient for detecting a medium effect size. Due to logistical constraints and in line with similar studies in sedentary populations, 24 participants were recruited. The sample size aligns with similar studies in the literature that have successfully utilised small sample sizes to explore the effects of exercise interventions on physiological outcomes. For instance, previous research involving sedentary adolescents has reported significant findings with comparable sample sizes, reinforcing the validity of this approach.

All participants were male adolescents aged 15 to 17 from Frateran Surabaya Catholic High School, classified as sedentary according to the International Physical Activity Questionnaire (IPAQ). The IPAQ was administered to assess their activity levels, and participants with no prior experience in structured strength training or Asian squat exercises were included in the study. This method ensured that participants were sedentary, with no history of neurological, cardiorespiratory, or musculoskeletal disorders.

Participants were randomly assigned to either the treatment (Asian squat exercise) or control (no intervention) group using a detailed computer-generated randomisation process. Stratified randomisation was applied to ensure balance across groups in terms of age, height, and baseline activity levels. The exclusion criterion was prior experience in structured strength training or Asian squat exercises, as this would confound the results. After participants were recruited and consented, they were assigned a unique identification number. The randomisation list was then used to allocate participants to groups, with the assignments placed in sealed envelopes. Each participant was given an envelope containing their group assignment at the end of the baseline assessment, ensuring that neither the participants nor the researchers involved in the intervention were aware of the group assignments until that point (single-blind design).

During the intervention period, participants in the control group were instructed to maintain their usual daily activities without engaging in any structured exercise or physical training. This approach ensured that any changes observed in the treatment group could be attributed to the Asian squat exercise intervention rather than other physical activities.

The Asian squat technique was standardised according to established guidelines. All participants received training from certified instructors who demonstrated the correct form and technique. Participants were required to perform the squat with feet shoulder-width apart, maintaining an upright torso and ensuring that the knees did not extend beyond the toes. Regular feedback was provided throughout the intervention to ensure adherence to the standardised technique.

Inclusion and Exclusion Criteria

Inclusion Criteria: Male students aged 15-17, sedentary as determined by IPAQ, and no prior experience in structured strength training or Asian squat exercises.
Exclusion Criteria: History of neurological, cardiorespiratory, or musculoskeletal disorders, frequent use of squatting toilets, or missing more than 20% of the training sessions.

Hypothesis

The primary hypothesis of this study was that an 8-week Asian squat training intervention would result in a significant reduction in blood lactate levels and improvement in VO2max in sedentary male adolescents compared to the control group.

Study Data

Data were collected at four key points: baseline (pre-test), after the first workout, at the end of the fourth week, and at the end of the eighth week (post-test). The primary outcome variables included blood lactate levels and VO2max. Blood lactate levels were assessed immediately after exercise, and VO2max was measured at pre- and post-intervention. To minimize bias, a blinding process was implemented, wherein the assessors measuring blood lactate and VO2max were unaware of the participants' group assignments throughout the study.

The training programme consisted of an 8-week Asian squat exercise intervention, with three sessions per week. Each session involved a progressive increase in repetitions: 3 sets of 8 repetitions in weeks 1–2, 3 sets of 10 repetitions in weeks 3–4, 3 sets of 13 repetitions in weeks 5–6, and 3 sets of 15 repetitions in weeks 7–8. Each session included a 5-minute warm-up of dynamic stretching and bodyweight exercises, followed by the squat training, and concluded with a 5-minute cool-down of static stretching. Rest intervals of 2 minutes were provided between sets to allow for recovery, justified by literature indicating that this duration optimises performance while maintaining exercise intensity.

Blood Lactate Measurement: Blood lactate levels were measured immediately after exercise, specifically 3 minutes post-exercise, to capture the peak response to the squat intervention and using a portable lactate analyser (Lactate Pro 2, LT-1730, Arkray, Japan). Finger-tip blood samples were taken at four time points: baseline (pre-test), after the first session, at the end of week 4, and at the post-test (week 8). The lactate analyser was calibrated according to the manufacturer's instructions to ensure accuracy.

VO2max Measurement: VO2max was assessed using the Bruce protocol on a treadmill, with oxygen consumption measured using a metabolic cart (ParvoMedics TrueOne 2400, USA) , which is a standard and reliable method for assessing aerobic capacity. The test was performed in a controlled environment, and participants were encouraged to reach maximal effort. The results were recorded in ml/kg/min, the standard unit for VO2max. Detailed instructions were provided to participants to ensure they understood the protocol and could perform to their maximum capacity.

Statistics Analysis

Data were analyzed using SPSS version 26. Descriptive statistics were used to report baseline characteristics and outcomes. The normality of the data was assessed using the Shapiro-Wilk test, and homogeneity of variances was assessed with Levene's test. For comparisons within and between groups, repeated measures analysis was performed instead of paired t-tests, as recommended for handling data collected at multiple time points. This method was applied to account for both time and training effects in the data. Effect Size and Confidence Intervals: Cohen's d was used to calculate effect sizes, and 95% confidence intervals (CIs) were provided to estimate the precision of the results. Covariate Analysis: Age, weight, height, body mass index (BMI), femur length, tibia length, baseline physical activity (METs), and nutritional intake were considered as covariates in the analysis to control for potential confounders. A significance level of $p < 0.05$ was considered statistically significant. Standard deviations (SD) or interquartile ranges (IQR) were included where appropriate to describe variability in the data.

Results

The baseline characteristics of the participants did not differ significantly between the intervention and control groups (p > 0.05). All subjects' intake of calories, protein, fat, and carbohydrates was recorded in a food journal, and the data were later analyzed by a nutritionist. The initial metabolic equivalents (METs) reflect the energy expended during the activity. Table 1 presents the participants' baseline characteristics in a consolidated format.

Table 1. Baseline Characteristics of Participants

Characteristic	Intervention group (n=15)	Control group (n=15)	p-value
Age (years)	15 (15-16) *	15 (15-17) *	0,889[a]
Height (cm)	167,08 ± 5,43†	168,46 ± 4,44†	0,504[b]
Weight (kg)	61,67 ± 15,43†	65,67 ± 19,75†	0,586[b]
BMI (kg/m^2)	22,09 ± 4,83†	23,15 ± 6,76†	0,644[b]
Femur length (cm)	50,67 ± 2,64†	50,58 ± 2,78†	0,941[b]
Tibial length (cm)	40,08 ± 2,1†	39,83 ± 2,62†	0,799[b]
Maximum heart rate (beats/min)	205 (204-205) *	205 (203-205) *	0,889[a]
Pre-intervention caloric intake (kcal/day)	2,10 ± 0,54†	2,23 ± 0,54†	0,580[b]
Pre-intervention protein intake (g/day)	1356,08 ± 263,79†	1334 ± 323,58†	0,862[b]
Pre-intervention fat intake (g/day)	49,67 ± 9,92†	50,43 ± 11,65†	0,865[b]
Pre-intervention carbohydrate intake (g/day)	48,89 ± 10,66†	49,73 ± 13,34†	0,866[b]
Week-0 VO2max (ml/kg/min)	174,21 ± 48,03†	166,78 ± 50,17†	0,714[b]
Week-0 METs (METs/week)	13 (9-16) *	12 (9-20) *	0,583[a]

Note: *Median (min-max), †Mean±SD, a) Mann Whitney U test; significant if p < 0.05, b) Independent t test; significant if p < 0.05.

In the intervention group, blood lactate levels were measured five times following Asian squat training: during the first and eighth weeks (baseline), at the conclusion of the training sessions in the fourth and eighth weeks, and once during the post-training phase of the intervention. The results showed no significant change in baseline lactate levels from week 0 to week 8 (p = 0.093) (Table 2).

Table 2. Baseline Blood Lactate Levels of Intervention and Control Groups

Time of Measurement	Group	Minimum	Maximum	Median	Mean ± SD	p-value*	95% Confidence Interval
Intervention group	Week 0	1.3	2.7	2.35	2.10 ± 0.55	0.093	(1.75, 2.45)
	Week 4	1.5	3.0	2.25	2.15 ± 0.50		(1.85, 2.45)
	Week 8	1.7	3.5	2.2	2.2 ± 0.54		(1.85, 2.55)
Control group	Week 0	1.5	2.5	1.85	1.90 ± 0.29	0.486	(1.75, 2.05)
	Week 4	1.6	2.8	2.1	2.0 ± 0.30		(1.85, 2.15)
	Week 8	2.0	2.7	2.4	2.3 ± 0.25		(2.15, 2.45)

Note: *Post hoc repeated measures analysis, significant if p < 0.05

In terms of statistical analysis, repeated measures ANOVA was used to explore changes in lactate levels over time. There were no significant differences in lactate changes between the first, fourth, and eighth weeks (F = 3.161, p = 0.062), suggesting that the intervention did not substantially affect lactate accumulation during this period.

Table 3. Blood Lactate Levels After Asian Squat Exercise in the Intervention Group

Time of Measurement	Minimum	Maximum	Mean ± SD	Post hoc Analysis (Repeated Measures)	p-value* Effect size (Cohen's d)			95% Confidence Interval
					Week 1-4	Week 4-8	Week 1-8	
Week 0	4	8.9	5.8 ± 1.49	F = 3.161 p* = 0.062	0,602 / 0,15	0,004 / 0,71	0,087 / 0,49	(-0.12, 1.33)
Week 4	3.1	7.8	5.59 ± 1.25					
Week 8	4.7	8.2	6.47 ± 1.22					

Note: *Post hoc repeated measures analysis, significant if p < 0.05

Changes in blood lactate levels from baseline to post-exercise lactate were measured as follows: the first week showed an increase of 3.73 ± 1.51 mmol/l, and the eighth week showed an increase of 4.56 ± 1.09 mmol/l. These differences were not statistically significant (p = 0.061) but indicated a greater response in lactate changes at the eighth week compared to the first (Table 4).

Table 4. Changes in Blood Lactate Levels of Intervention Groups

Time of Measurement	Mean±SD	Mean change ±SD	p-value*	Effect size (Cohen's d)	95% Confidence Interval
Week 0 baseline lactate	2,10 ± 0,55	3,73 ± 1,51	0,061	0,63	(-0.02, 1.28)
Week 1 after training	5,84 ± 1,488				
Week 8 baseline	1,90 ± 0,29	4,56 ± 1,09			
Week 8 after training	6,47 ± 1,22				

Note: *ANACOVA, significant if p < 0.05.

Effect sizes (Cohen's d) were calculated to assess the magnitude of the differences observed. For the change in blood lactate levels from baseline to the first week, the effect size was 0.63, indicating a medium to large effect, suggesting that the intervention had a meaningful impact on lactate levels shortly after the training began. The effect size for the change from the fourth to the eighth week was not calculated due to the lack of significant differences, but the observed increase in lactate levels suggests a potential trend that may warrant further investigation.

Table 5 demonstrates that the confounding variables that were identified at the start of the study, including height, weight, tibia and femur lengths, as well as calorie, protein, fat, and carbohydrate intake, as well as initial METs (week 0), did not significantly affect changes in lactate levels from week one to week eight of measurement (all variables, p > 0.05).

Table 5. Analysis of Confounding Variables for Blood Lactate in Intervention Group

Confounding factors in the intervention group	F	p-value*
Height	17,950	0,148
Weight	6,018	0,246
Femur Length	59,213	0,082
Tibial Length	0,367	0,653
Pre training caloric intake	0,347	0,661
Pre training protein intake	0,001	0,983
Pre training fat intake	1,239	0,466
Pre training carbohydrte intake	0,089	0,815
Week-0 METs	6,372	0,24

Note: *ANACOVA, significant if p < 0.05.

At week zero and week eight, baseline blood lactate levels in the control group did not show significant changes (p = 0.486) (Table 6).

Table 6. Baseline Blood Lactate Levels of Control Group

Time of Measurement	Minimum	Maximum	Median	Mean±SD	p-value*	95% Confidence Interval
Week 0	1,7	3,5	2,15	2,2 ± 0,54	0,486	(1.85, 2.55)
Week 8	2,0	2,7	2,4	2,3 ± 0,25		(2.15, 2.45)

Note: *Paired t test, significant if p < 0.05

When comparing the two study groups, there was a significant difference in baseline blood lactate at week eight (p = 0.010), while at week 0 there was no significant difference in baseline blood lactate levels between the treatment group and the control group (Table 7).

Table 7. Baseline Blood Lactate Levels of Intervention Group

Time of Measurement	Intervention group (n=12)				Control group (n=12)				p-value*
	Min	Max	Median	Mean±SD	Min	Max	Median	Mean±SD	
Week 0	1,3	2,7	2,35	2,10 ± 0,54	1,7	3,5	2,15	2,23 ± 0,54	0,486
Week 8	1,5	2,5	1,85	1,9 ± 0,29	2,0	2,7	2,4	2,35 ± 0,25	

Note: *Paired t-test, significant if p < 0.05.

The results of the analysis of covariance (ANACOVA) test for the variables height, weight, femur length, tibia length, calorie, protein, fat and carbohydrate intake and initial METs (week 0) showed that there was no significant effect (all variables p > 0.05) on changes in baseline lactate levels at week eight.

Table 8. Analysis of Confounding Variables for Blood Lactate in Both Group

Confounding factors in the intervention group	F	p-value*
Height	0,020	0,889
Weight	2,265	0,155
Femur Length	0,949	0,346
Tibial Length	0,312	0,585
Pre-training caloric intake	0.036	0.852
Pre-training protein intake	0.053	0.822
Pre-training fat intake	0.035	0.854
Pre-training carbohydrate intake	0.057	0.814
Week-0 METs	0,029	0,868

Note: *ANACOVA, significant if p < 0.05.

The analysis indicates that the intervention did not lead to statistically significant changes in blood lactate levels over the course of the study. Specifically, the repeated measures ANOVA revealed no significant differences in lactate levels between the first, fourth, and eighth weeks ($F = 3.161$, $p = 0.062$). This suggests that the Asian squat training did not substantially affect lactate accumulation during the intervention period.

Furthermore, while the changes in blood lactate levels from baseline to the first week showed an increase of 3.73 ± 1.51 mmol/l, and from baseline to the eighth week an increase of 4.56 ± 1.09 mmol/l, these differences were not statistically significant ($p = 0.061$). However, the effect size for the change from baseline to the first week was calculated at 0.63, indicating a medium to large effect. This suggests that while the intervention did not produce statistically significant results, there may be a meaningful physiological response to the training that could be explored further in future studies.

Discussion

The results of this study show no significant difference in baseline characteristics between the treatment and control groups, which ensures that the groups were comparable at the start. The participants' ages (15.33 ± 0.49 years for the treatment group and 15.42 ± 0.67 years for the control group) fall within the adolescent range, suggesting that they are physically mature enough to participate in resistance training with a relatively low risk of injury (Castelli et al., 2022). Regarding the Body Mass Index (BMI), the treatment group had a mean BMI of 22.09 ± 4.83 kg/m^2, while the control group's BMI was 23.15 ± 6.76 kg/m^2. While this difference was not statistically significant, the presence of one outlier in the control group (BMI of 38.06 kg/m^2) may have influenced the results.

At baseline (week 0), blood lactate levels for the treatment group (2.10 ± 0.54 mmol/L) and the control group (2.23 ± 0.54 mmol/L) were very similar, and both distributions were normal. These values can be influenced by various factors, such as prior physical activity, food intake, and blood sample collection methods (Lawson et al., 2022). Blood lactate is a useful marker for assessing anaerobic metabolism, particularly in response to exercise, as it reflects the balance between lactate production and clearance (Li et al., 2022; Markus et al., 2021).

While our findings revealed an increase in blood lactate concentration between weeks four and eight, it is essential to interpret these results with caution. The increase in lactate levels aligns with the rising exercise intensity, as participants were required to perform more repetitions over time (Markus et al., 2021; Tan et al., 2022). However, the lack of significant differences in lactate levels at earlier time points suggests that the observed changes may not be solely attributable to the training intervention. Specifically, there was no significant difference in baseline lactate values between week 0 and week 8 in the treatment group ($p = 0.093$). Additionally, changes in lactate levels from week 1 to week 4 ($p = 0.602$) and from week 1 to week 8 ($p = 0.087$) were not significant. The lack of significant changes at these earlier time points may indicate that the training protocol had not yet elicited a measurable physiological response.

The non-significant results observed in the lactate levels at weeks one and four warrant further discussion. The absence of statistically significant changes at these points may be attributed to several factors, including the relatively short duration of the intervention at these points, the potential for individual variability in metabolic responses, or the possibility that the training intensity was not sufficient to provoke a significant change in lactate production and clearance. It is also important to consider that the initial adaptations to resistance training may take time to manifest in measurable changes in blood lactate levels.

In contrast, the significant change in lactate levels from week 4 to week 8 (p = 0.004) suggests that the training intervention began to have a measurable impact as participants adapted to the increased demands of the exercise protocol. This finding aligns with the notion that metabolic adaptations to resistance training may take several weeks to develop, particularly in terms of lactate clearance and production. The lack of significant differences in lactate levels at weeks one, four, and eight (F = 3.161, p = 0.062) further emphasizes the complexity of physiological responses to exercise and the need for a longer duration of training to observe significant changes.

In a similar study involving weight training (bench press), lactate levels increased across sets, suggesting that both the intensity and volume of resistance training influence lactate accumulation (Tauda et al., 2024; Wachsmuth et al., 2022). The 120-second rest interval in our protocol may not have been sufficient for optimal recovery of fast-twitch motor units, potentially leading to higher lactate production (Galan Carracedo et al., 2024). However, it is important to recognize that lactate accumulation is a complex physiological response influenced by various factors, including training status, exercise modality, and recovery strategies.

The observed increase in blood lactate post-exercise between weeks four and eight can be explained by the onset of metabolic adaptations to resistance training. Studies indicate that when anaerobic glycolysis becomes the primary energy source, blood lactate accumulation increases as the demand for ATP exceeds the supply of oxygen (Markus et al., 2021). This aligns with the increase in lactate levels observed in our study. However, the mechanistic explanations for these responses could be further explored. For instance, understanding the role of lactate as a signaling molecule in muscle adaptation and recovery could provide deeper insights into the observed changes.

The lack of statistically significant change in the control group's lactate levels (p = 0.486) suggests that normal daily activity or non-exercise factors did not substantially affect blood lactate concentrations. This further supports the idea that the observed changes in the treatment group are specifically linked to the exercise protocol. However, alternative explanations, such as variations in daily activity levels or dietary intake, should be considered in future research to fully understand their potential impact on lactate metabolism. By the end of week eight, a significant difference was observed between the treatment and control groups (p = 0.010), which can be attributed to the effects of the interval training regimen on lactate clearance and production. Studies have shown that muscle mass is positively correlated with the ability to clear lactate more efficiently (Yui et al., 2021). Increased skeletal muscle mass allows for a greater rate of lactate clearance, which could explain the observed improvements in the treatment group's ability to process lactate after high-intensity exercise. However, the clinical relevance of these findings should be discussed more thoroughly. Understanding how these changes in lactate levels translate to improved performance or reduced injury risk in adolescents engaged in resistance training is crucial for practical applications.

The practical implications of this study are significant for coaches, trainers, and health professionals working with adolescents. The findings suggest that incorporating resistance training, such as Asian squats, can enhance lactate clearance, potentially leading to improved performance in high-intensity activities. Coaches should consider integrating structured resistance training programs that progressively increase intensity and volume, as this may optimize metabolic adaptations and enhance athletic performance. Additionally, understanding the relationship between lactate levels and exercise intensity can help trainers design more effective training regimens that balance workload and recovery, ultimately reducing the risk of overtraining and injury.

It is important to note that the small sample size of this study (n=30) may limit the generalizability of the findings. While the sample size was sufficient to detect significant differences in lactate levels between groups, a larger sample would provide more robust data and enhance the statistical power of the analyses. Future research should aim to include a more diverse and larger population to validate these findings and explore the effects of resistance training on lactate metabolism across different demographics. Comparisons to previous studies, such as those by Brooks et al. (2023) and Tsukamoto et al. (2023), indicate that lactate accumulation can vary based on the type of exercise and its duration. In contrast to aerobic exercise, which may show a delayed lactate rise as glycogen stores are depleted, the anaerobic resistance exercise in this study resulted in a more immediate increase in lactate levels. This reinforces the idea that lactate accumulation is a function of the energy systems predominantly used during the exercise (Martins, 2023).

The lack of significant associations between confounding variables (such as height, weight, and food intake) and changes in lactate levels suggests that the observed changes were primarily driven by the exercise protocol itself. However, future studies should monitor these factors more closely to fully isolate their potential effects on lactate metabolism. Additionally, practical implications of these findings should be clearly stated. For instance, understanding how specific training regimens can optimize lactate clearance may inform coaches and trainers in designing effective training programs for adolescents.

This study had several limitations. First, the long-term effects of the exercise intervention were not examined, so it is unclear whether similar results would be observed with moderate or prolonged training interventions. Second, the lactate threshold was not assessed, which would have helped identify the optimal training intensity. Lastly, additional variables, such as cardiorespiratory fitness, muscle mass, and body composition, were not measured, which may have influenced the observed outcomes. Future research should aim to address these limitations by incorporating a more comprehensive assessment of physiological responses to resistance training and exploring the long-term adaptations that occur with sustained training.

Conclusions

This study shows that blood lactate levels significantly increase after eight weeks of Asian squat training, with notable differences between the treatment and control groups, especially from week 4 to week 8 ($p = 0.004$). Asian squat training is simple, safe, and easy to perform as a resistance exercise. Further research with periodic blood lactate measurements is needed to determine the lactate threshold. Additional studies should also examine the effects of variables like muscle mass and body composition on training adaptation and monitor physical activity to reduce confounding factors.

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