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Review Article

Virtual reality: applications, mechanisms, and rehabilitation implications: a narrative review

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ABSTRACT

Background: Virtual Reality (VR) is an emerging technology that creates immersive, interactive environments, offering real-time feedback, task-specific repetitive practice, and gamified exercises that enhance neuroplasticity, motivation, and adherence during rehabilitation.

Objective: To synthesize current literature on VR applications, mechanisms of action, and rehabilitation outcomes across diverse populations.

Methodology: A comprehensive literature search was conducted in Google Scholar, PubMed, Elsevier, and JSTOR for studies published between 2015 and 2024. Randomized controlled trials, quasi-experimental trials, pilot studies, systematic reviews, and meta-analyses using VR as a primary intervention in rehabilitation were included in the review. Data were extracted on study design, sample characteristics, type of VR intervention, duration, and motor or functional outcomes. Twelve studies meeting inclusion criteria were synthesized narratively, highlighting intervention types, effects, and trends across patient populations.

Results: VR-based interventions demonstrated significant improvements on upper and lower limb motor function, gait, balance, and independence in post-stroke patients. While the Parkinson's patients exhibited enhanced postural control, gait, and reduced fall risk. Intensive VR-based exergaming showed great improvement in gross motor function and coordination as well as engagement and motivation in children with cerebral palsy. In older adults' VR improved balance, dual-task walking, and functional mobility. High satisfaction and tolerability were indicated as patients reported consistent improved outcomes. Despite these benefits, low awareness, training gaps, and equipment costs have reduced its adoption in clinical settings. Low cost VR solutions can be safely employed in resource-limited clinical settings as suggested by feasibility studies.

Conclusion: Motor recovery, neuroplasticity as well as patient engagement are greatly improved with use of VR based therapy as it is a promising adjunct to traditional exercises and conventional rehabilitation.

Keywords: cerebral palsy; neurological deficits; rehabilitation; stroke; virtual reality.

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INTRODUCTION

Virtual reality (VR) is a technology that creates immersive, interactive 3-D environments by simulating real or imagined worlds [1]. In rehabilitation, movements and activities of daily living can now be practised in safe, controlled, and engaging virtual settings[2, 3]. Recent advances in VR such as affordable head-mounted displays, motion-capture sensors, and integration with telemedicine and AI - have greatly expanded its use in healthcare and physiotherapy[2, 4]. Home and clinics now have easy access to VR due to recent developments. The ability to precise tracking and feedback on patient performance has enhanced[4].

The gamified and task-oriented exercises through VR has strongly enhanced motor learning and coordination. VR accelerates motor skill acquisition more effectively than conventional therapy by providing real-time visual and haptic feedback on movement. Various systematic reviews have reported that intensive, repetitive practice with immediate performance feedback through VR-rehabilitation, drive neuroplasticity and skill retention[3, 5]. VR environments can be tailored and adjusted to specific patient's ability level, thus increasing engagement and motivation during therapy[3, 4]. Importantly, VR training stimulates synaptic plasticity in the brain by activating neural circuits associated with reward and motor planning, thereby stimulating synaptic plasticity in the brain[2, 5].

VR interventions which are fully-immersive have shown significant effect across various patient populations. VR training improved upper-limb functions, gait, balance, and independence, with improved motor skills to real-world tasks in post-stroke rehabilitation[3,6]. Among Parkinson patients, VR-based balance and gait exercises, have improved the postural control, walking ability, and reduced fall risk. This also stimulated automatic motor pathways and cognitive processes[3,5]. VR modifies therapy as engaging and less fatiguing. Intensive training showed positive improvements in gross motor skills and coordination in the upper limb function in CP children[7]. Among older adults, VR-based exercise programs showed improvements in gait speed, dual-task walking, and overall mobility. Reduction in fall-risk markers and dual-task costs were also noted. The older adults achieved safer and more confident ambulation[8].

Due to lack of awareness and training in VR, it is still under-utilized and less explored in many clinical settings[9]. High quality VR requires costly reliable hardware and sometimes custom software, creating technical hurdles[4]. There are also limited clinical guidelines for VR integration, and concerns related to patient safety. Collectively, these issues and barriers contributed in lack of use of VR in rehabilitation practice.

Hence an updated narrative review is needed as the VR technologies are undergoing rapid evolution and the evidence base is growing. Such as low-cost and high-end systems, clarify the underlying mechanisms of examine the feasibility for implementation of VR in resource-limited clinical settings. As healthcare systems strive to expand rehabilitation access worldwide, it is crucial to highlight potential of VR as well as its limitations in low-resource contexts. By covering the latest innovations, outcomes, and real-world challenges, this review aims to guide clinicians and policymakers on harnessing VR's full promise in rehabilitation.

METHODOLOGY

Study Design: For this narrative review the Scale for the Assessment of Narrative Review Articles (SANRA) guidelines was used, in the study to be transparent, comprehensive, and methodologically sound accuracy. The *objective was to summarize the literature on Virtual Reality (VR) as an intervention* in rehabilitation settings.

Search Strategy: To conduct a comprehensive literature search the Google Scholar, PubMed, Elsevier, and JSTOR were used. The main focus of the search strategy was to explore the studies using VR in rehabilitative interventions, published between 2015 and 2024. The virtual reality, cerebral palsy, stroke, neurological deficits, motor declines, healthy older adults, and community dwelling individuals were the keywords used for literature search by applying Boolean operators (AND, OR) to refine the search results. The reference lists of relevant articles were also screened to identify the more studies.

Inclusion and Exclusion Criteria: The studies included in this review are the pilot studies, randomized controlled trials, quasi experimental, systematic reviews and meta-analysis conducted on human participants in which primary intervention was the VR in healthcare or rehabilitation. The studies lacking a clear methodological description, focusing primarily on teacher, parent, or caregiver perspectives rather than participant outcomes, were excluded.

Study Selection: Following the screening of databases and abstract review of the articles, a total of n=12 meeting the inclusion criteria were selected for synthesis. A range of research designs represented in the selected articles were the randomized controlled trials, quasi-experimental trials, pilot studies, systematic reviews, and meta-analyses.

Data Extraction and Synthesis: Data were extracted on the study designs, sample characteristics, types of VR intervention, duration, and outcomes related to motor and functional performance. There was no statistical method was used for data collection but narratively synthesized to highlight the trends, similarities, and variations among studies. Several studies have consistently shown that virtual reality can be a valuable tool in rehabilitation. Various VR platforms were included used in previous researches, such as Nintendo Wii, Microsoft Kinect, Mandala Gesture Xtreme, and PlayStation-based systems. The duration of VR programs varied widely, from 10-minute sessions to several weeks, showing that these interventions can be easily adapted for different age groups and rehabilitation settings.

RESULTS

The narrative summery table of n=12 studies highlighting the main results, study features, types of VR interventions, their duration, and the functional outcomes reported. It also shows the current trends; VR effectiveness and approaches can be applied in clinical practice.

Table 1: Overview of VR Interventions and Outcomes

Ref #	Study	Design	Sample Characteristics	VR Intervention Type	Duration	Outcomes Related to Motor/Functional Performance
[10]	Zhang et al. (2025)	Network meta-analysis	Stroke patients	Non-immersive VR (Kinect)	Varies across trials	Significant improvement in upper-limb motor function
[5]	De Natale et al. (2025)	Meta-analysis	Parkinson's disease patients	Immersive VR balance training	Varies	Improved postural control (SMD=0.58)
[11]	Tobaiqi et al. (2023)	Systematic review/meta-analysis	Children with cerebral palsy	Exergaming platforms (Nintendo Wii, Kinect)	4-8 weeks	Improved gross motor skills and functional activity
[12]	Zak et al. (2024)	Randomized controlled trial	Older women, aged 65+	Immersive VR + Otago exercise	8 weeks	Enhanced balance, functional mobility
[13]	Baníková et al. (2025)	Pilot study	Sub-acute ischemic stroke patients	Immersive VR (head-mounted display)	2 weeks	High patient satisfaction, improved tolerance
[14]	Mesa-Burbano et al. (2025)	Systematic review	Children with CP	Various VR platforms	2-12 weeks	Enhanced coordination, attention, motivation
[15]	Slatman et al. (2024)	Survey	Dutch physiotherapists	Various platforms (low use)	N/A	7% VR use; main goals: pain relief, coordination
[16]	Morris et al. (2010)	Feasibility study	Adult burn patients in South Africa	Low-cost immersive VR (headset)	Single-session trials	Trend toward pain and anxiety reduction
[2]	Capriotti et al. (2025)	Review	Mixed populations	Multiple VR types	Variable	Functional gains across stroke, MS, Parkinson's
[17]	Solares et al. (2025)	Systematic review	Neurodegenerative disease patients	VR for physical rehab	4-12 weeks	Improved gait, strength, tolerability noted
[3]	Cardile et al. (2025)	Systematic review	Post-stroke patients	Semi-immersive, immersive VR	2-6 weeks	76.3% of interventions yielded motor improvements
[18]	Lu et al. (2025)	Meta-analysis	Stroke survivors	VR-based lower-limb training	Varies across studies	Significant gains in mobility and gait performance

DSCUSSION

The current study's objective was to synthesize current literature on VR applications, mechanisms of action, and rehabilitation outcomes across diverse populations, and also examined barriers to clinical adoption and feasibility in low-resource settings. Recent evidence strongly supports the efficacy of VR-based rehabilitation across a variety of conditions. Combined immersive VR and conventional therapy significantly improved postural balance in Parkinson's disease, compared to conventional therapy alone, as investigated in a meta-analysis conducted in 2025[5]. Similarly, in stroke recovery, non-immersive VR (using devices like the Microsoft Kinect) was the most effective modality for improving upper limb motor function as reported in a systematic review (2025)[10]. Another meta-analysis showed that VR-based exercise substantially enhanced lower-limb mobility after stroke [18]. A review also noted that the majority of VR interventions (76.3%) produced positive motor outcomes among post-stroke patients, with semi-immersive systems yielding the highest proportion of improvements. These findings indicate that VR can be an effective adjunct to standard therapy for neurological conditions, engaging patients with motivating, task specific exercises and potentially facilitating neuroplasticity[3].

Virtual reality is also being applied in pediatric and geriatric rehabilitation. In children with cerebral palsy (CP), systematic reviews have found that VR interventions lead to improvements in gross motor

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function, balance, and upper limb coordination, while also increasing engagement and motivation[14]. One systematic review and meta-analysis specifically reported that VR-assisted exergaming produced significant improvement in motor skills for children with CP[11]. Among older adults, the studies also encouraged that a fully immersive VR exercise program combined with dual-task cognitive components significantly improved balance in older women, beyond what was achieved with conventional Otago exercises[12]. In general, these studies reported that participants perceived VR-based exercises as enjoyable as and less burdensome than traditional therapy, and outcomes often included measurable gains in strength, coordination, and functional mobility[3,12,14].

Patient reported positive outcomes on VR rehabilitation in a pilot study of subacute stroke patients, with very high levels (68%) of satisfaction and tolerability with VR therapy. Patients rated clarity of information and perceived therapeutic benefits[13]. These findings align with other reports that VR's immersive and interactive nature tends to enhance motivation and engagement during therapy.

There is a limitation in definite adoption of VR in clinical settings, despite having immense potential. Only about 7% primary care physiotherapists had integrated VR into treatment for chronic pain conditions in a survey conducted in Netherlands recently. Those who primarily used VR for lessening pain and enhancing coordination, rated their experience moderately positive. A very small percentage of physiotherapists have adopted VR since the past two years[15]. Deficiency of familiarity and training with the technology as well as restricted resources became the major barriers to wider use of VR. Increased engagement of VR in clinical practice could be augmented through rigorous training and evidence.

In resource-limited settings, low-cost VR can be feasible and beneficial as shown in various pilot studies. A feasibility trial conducted in South Africa used an inexpensive head-mounted display during physiotherapy for adult burn patients. Although, statistically significant pain reduction was not noted (likely due to limited sample size), there was a trend toward improved pain and anxiety outcomes when VR was added to standard analgesia[16]. Importantly, the study advocated the use of inexpensive VR setups to be safe and well-tolerated. They could potentially be implemented in low-resource burn units[16]. Hence, in low- and middle-income countries (LMICs), where conventional rehab resources are scarce; low-cost and consumer-grade VR systems could be adopted for rehabilitation.

Overall, there is a need for more high-quality trials as noted by recent review articles advocating the benefits of VR in rehabilitation. VR-based exercises greatly improve strength, skill, and mobility across conditions. Secondly, users found VR-based therapy more engaging than traditional exercises as highlighted by published reviews[2,3]. Another review was conducted which focused on neurodegenerative diseases like Parkinson's, multiple sclerosis. They similarly concluded VR interventions to be effective and well-tolerated, though it called for larger RCTs to confirm long-term benefits[17].

This review employed a narrative synthesis rather than a Meta analytic approach, despite providing a comprehensive synthesis. Further, direct comparability and generalization of findings were restricted due to substantial heterogeneity. There is also publication biasness as studies with null or negative findings remain under-represented while those reporting positive outcomes become likely to be published.

CONCLUSION

Virtual reality (VR) is a powerful alternative to the conventional rehabilitation. To recognize the maximum potential of the VR, large scale trials with longer follow-ups and standardized outcome measures should be focused and explored in future researches. In order to improve real world recovery and quality of life for patients with neurological and musculoskeletal conditions; advances like VR-based rehab could become a routine, evidence-based option.

DECLARATIONS & STATEMENTS

Author's Contribution

SG: substantial contributions to the conception and design of the study.
SG, and AS: acquisition of data for the study.
AS and KB: analysis and interpretation of data for the study
SG and KB: drafted the work.
SG, AS and KB: revised it critically for important intellectual content.
SG, AS and KB: final approval of the version to be published and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

This narrative review uses only published literature and involves no human or animal subjects; therefore, no ethical approval or consent was required. All sources were appropriately cited and ethical standards were followed.

AI Use Statement

The authors used Grammarly to improve language clarity during manuscript preparation. Generative AI tools such as ScisSpace and Semantic Scholar were used to assist with literature summarization and refinement of the research rationale. All interpretations, conclusions, and original ideas remain solely those of the authors and approved by the authors.

Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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None to declare.

Conflicts of Interest

None to declare.

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Research Article

Effects of soleus push-ups on lipid profile among young population

Mehnoor Butt[1]*, Sara Noor [1], Obaid Baig Mirza[2], Abdul Quddoos[3]

Abstract

Background: Recent interest has emerged in soleus push-ups, due to the unique physiological characteristics to sustain prolonged activity. These exercises can be performed with minimal equipment, and may offer a practical alternative for sedentary individuals for acute lipid profile responses.

Objective: To evaluate the effects of moderate intensity and sustained soleus pushups on lipid profile level in sedentary young adults.

Method: A randomized controlled trail was conducted on n=33 sedentary healthy young, aged 18 to 35 years. Participants were placed into three groups: Group A did moderate-intensity soleus pushups, Group B did continuous soleus push-ups, and Group C served as a control group. The primary outcome measure was the change in lipid profile, including high-density lipoprotein, lower cholesterol, total cholesterol and triglycerides was gathered at baseline and after 4.5 hours of intervention.

Results: Within-group analysis revealed significant changes in lipid profiles. In MSPU, HDL (p=0.028), total cholesterol (p=0.024), and triglycerides (p=0.005) increased, while LDL was unchanged. SSPU showed reduced LDL (p=0.013) and increased triglycerides (p=0.005). Control group had increases in HDL (p=0.020), total cholesterol (p=0.010), and triglycerides (p=0.010), with non-significant LDL changes. Between-group differences were non-significant (p≥0.05).

Conclusion: The findings reveal that moderate and continuous push-ups have varied impacts on sedentary youth's lipid profile. Although HDL, triglycerides, and total cholesterol levels varied considerably across groups, LDL levels did not. Triglyceride levels changed significantly at baseline and four hours after the intervention. These findings emphasize the need of examining various attempts to promote lipid metabolic alterations in isolated individuals.

Keywords: High Density Lipoproteins (HDL), Lipid Profile, Low Density Lipoproteins (LDL), Moderate intensity exercise, Physical activity, Short duration exercise, Soleus push-ups, Sustained exercise, Triglycerides, Young population.

Clinical trial # NCT06326788

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INTRODUCTION

The lipid profile with elevated triglycerides, low high-density lipoprotein cholesterol (HDL-C), and abnormal low-density lipoprotein cholesterol (LDL-C), is increasingly prevalent among young adults due to sedentary lifestyles, low physical activity and prolonged sitting[1]. Early alterations in lipid profile during youth are clinically significant, as they contribute to the early development of atherosclerosis and increase the long-term risk of cardiovascular and metabolic diseases[2].

The effects of exercise has been shown to induce desirable changes in plasma lipid levels, particularly an increase in high-density lipoprotein (HDL) and a decrease in triglycerides (TG)[3]. Endurance training (ET) offers metabolic benefits, including improved lipid profiles, body fat, and blood sugar control[4]. Physical activity is a well-established conservative management to improve lipid metabolism. However, moderate-to-vigorous aerobic activities are often emphasized[3]. These activities are usually difficult to adopt or sustain among young individuals due to time restraints, low motivation, or predominantly sedentary routines. Consequently, localized, low-threshold exercises are gaining interest, as can be frequently perform with minimal equipment[5,6]. Despite convincing evidence, challenges remain in the feasibility and accessibility of regular exercise.

Soleus push-ups, targeting the soleus muscle, improve oxygen consumption, blood sugar levels, and triglycerides. Sustained soleus push-ups involve prolonged, high-intensity contractions, enhancing endurance and stability, while moderate soleus push-ups are shorter and lower intensity, enhancing strength and flexibility[7]. This study compares moderate and sustained soleus push-ups, each exerting unique physiological impacts. By evaluating the effects of these exercises on lipid profiles among young people, this research aims to establish soleus push-ups as a practical, low-cost strategy to improve metabolic health and reduce cardiovascular risks among young populations globally. This research fills critical gaps in understanding the acute impacts of soleus push-ups on lipid levels, providing insights into preventive health measures for chronic metabolic diseases.

METHODOLGY

Study design: A single blinded, crossover, randomized clinical trial was initiated after getting approval from the Research Ethic Committee (Riphah/RCRAHS-ISB/REC/MS-PT/01819) of Riphah International University, Islamabad. The study was conducted at Pakistan Railway General Hospital from March 2024 To June 2024. The purpose of the study was explained to the subjects and written informed consent in accordance with Deceleration of Helsinki was obtained.

Selection criteria: A non-probability convenient sampling technique was employed for sample collection, focusing on participants who met specific inclusion criteria: adults aged 18-35, healthy BMI, gender equality, and a sedentary lifestyle. Exclusion criteria was individuals with a history of metabolic disorders, recent fractures, lower-limb injuries, knee injuries, those following a prescribed diet and exercise routine, any congenital abnormalities, deep vein thrombosis (DVT), lower limb amputations, or diagnosed hyperlipidaemia. Participants not meeting these criteria were excluded from the study.

Sample size: The total sample size was calculated by G-power. This study would contain a total of 33 participants, divided into two groups of 11 each. The effect size is 0.25, the alpha error probability is 0.05, and the power is 0.85. A total of n=33 participant was then randomly divided into three groups A (n=11), group B (n=11) and control group (n=11).

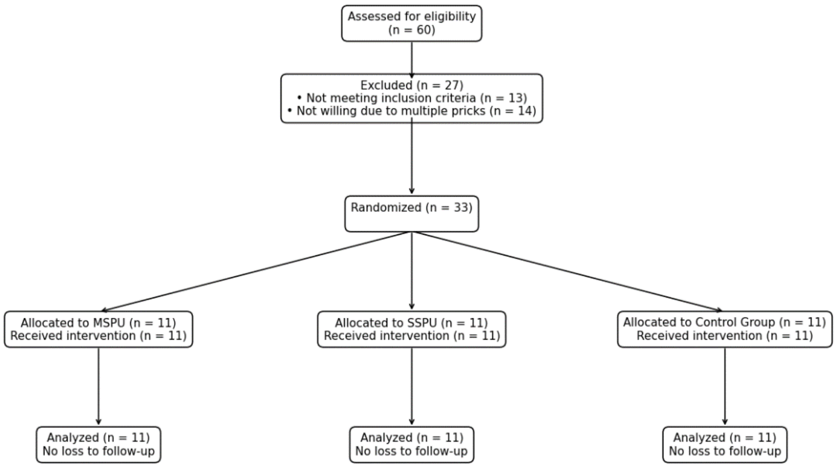

Figure 1: Consort Diagram

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Randomization: To avoid selection bias and allow for group comparisons, individuals were assigned to one of three groups using random allocation software 2.0. Each participant was given a unique identification, and a random list was created to divide them into three groups: mid-soleus push-up (MSPU), sustained soleus push-up (SSPU), and control. The deployment order remains concealed until the intervention is deployed. Participants learned about group assignments only after the baseline exam was finished. The randomization list was kept hidden from the study coordinators, who assigned participants in sealed opaque envelopes following a specified methodology.

Intervention: The intervention detail was explained to subjects and none of the participants were harmed during the study. Participants were divided into three groups for the study. The intervention group, Group A, performed moderate soleus push-ups with resistance until they reached their maximum heart rate (MHR). Group B conducted sustained soleus push-ups for up to 270 minutes. While the control group did not received any intervention. This design aimed to compare the effects of different durations and intensities of soleus push-ups on participants. These all exercises were performed by the participants actively under supervision after being demonstrated by the therapist, inside the physiotherapy OPD Pakistan Railway General Hospital. (Table 1)

Table 1: Intervention Protocol

Group A (MSPU)	Group B (SSPU)	Group C (Control)
Participants started soleus push-ups in sitting positions. To do so, the participants were seated position, the legs were at 90 degrees to the floor, feet placed flat on the ground. Participants then moved their heels up and down continuously. Soleus push-ups performed with moderate intensity using weights placed on their laps. The weight was calculated from 1RM of 30-40% of soleus muscle's strength for time till muscle fatigued.	Participants started soleus push-ups in sitting. To do so, the participants were in a seated position, the legs were at 90 degrees to the floor, and feet were placed flat on the ground. Participants then move their heels up and down continuously. Sustained soleus push-ups performed without any resistance, light intensity for up to 4.5 hours. Participants were provided with a maximum 4-minute break time after every 90-minute intervention.	No intervention

Data Collection Procedure: The purpose of the study explained to the participants. Written informed consent taken. All participants have had the same breakfast, and after 30 minutes of the breakfast, baseline data of lipid profile was taken. The participant then performed soleus push-ups as mentioned in table 1. The second sample for lipid profile was obtained after 4.5 hours. The blood sample was collected by qualified lab technologist.

Outcome Measures: The primary outcome measure of this study is the lipid profile, comprising total cholesterol (TC), HDL cholesterol (good cholesterol), LDL cholesterol (bad cholesterol), and triglycerides. These components are crucial indicators of cardiovascular health and metabolic function.

Statistical methods: For within group changes after 4.5 hours, the paired sample test was used. While for group differences One-way ANOVA test was used. The level of significance was set at $p<0.05$ and SPSS version 2 was used to analyse the data.

RESULTS

The mean age of participants as 23.88±2.42 (min 18 and max 35) years. While the BMI ranges from 22.13 to 23.01, with a mean of 23.36±4.91. All descriptive statistics are based on a valid sample of n=33 individuals.

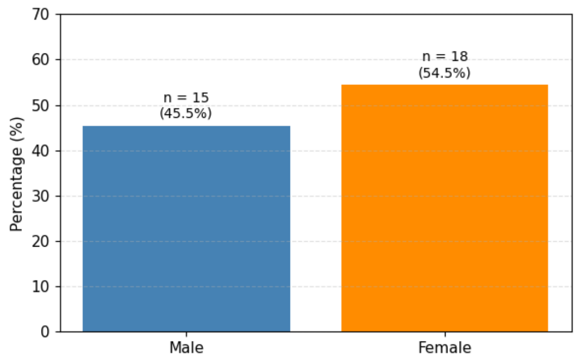

Figure 2: Gender

The paired sample t-test analysis showed different patterns of lipid profile changes across the three groups from pre- to post-intervention. In the MSPU group, statistically significant increases were observed in HDL (p=0.028, d=-0.586), total cholesterol (p=0.024, d=-0.607), and triglycerides (p=0.005, d=-0.786), while LDL showed no meaningful change (p=0.820). The SSPU group demonstrated a unique and favorable significant reduction in LDL (p=0.013, d=0.709) alongside a highly significant increase in triglycerides (p=0.005, d=-0.833), with HDL and total cholesterol showing non-significant increases (p≥0.05). The Control group exhibited significant increases in HDL (p=0.020, d=-0.627), total cholesterol (p=0.010, d=-0.710), and triglycerides (p=0.010, d=-0.711), with LDL showing a non-significant (p=0.056) increase. (table 2) One-way ANOVAs showed no significant (p≥0.05) between-group differences for HDL, LDL, total cholesterol, or triglycerides. (Figure 3)

Table 2: Pre-post Results lipid profile

Group	Lipid Marker	Pre Mean±SD	Post Mean±SD	MD	p-value	Cohen's d
MSPU	HDL	33.80±8.01	35.07±8.75	-1.27	0.028*	-0.586
	LDL	152.13±39.88	152.99±34.89	-0.86	0.820	-0.056
	CHOL	157.18±21.21	164.12±23.43	-6.94	0.024*	-0.607
	TRIGLY	96.41±31.30	137.76±72.26	-41.35	0.005*	-0.786
SSPU	HDL	31.96±5.56	32.55±5.96	-0.59	0.176	-0.355
	LDL	173.84±35.15	165.21±38.95	8.63	0.013*	0.709
	CHOL	159.81±27.81	162.75±29.80	-2.94	0.176	-0.355
	TRIGLY	89.69±43.94	150.56±109.07	-60.88	0.005**	-0.833
Control	HDL	33.25±6.55	35.20±7.97	-1.95	0.020*	-0.627
	LDL	169.18±39.08	174.71±38.33	-5.53	0.056	-0.499
	CHOL	161.24±28.82	167.76±29.04	-6.53	0.010*	-0.710
	TRIGLY	82.18±34.51	100.12±35.68	-17.94	0.010*	-0.711

Statistical significance- p<0.05p<0.05
Cohen's d- effect size- small (-0.2); medium (-0.5); large (-0.8); MSPU- mid-soleus push-up; SSPU- sustained soleus push-up; HDL-High-Density Lipoprotein; LDL-Low-Density Lipoprotein; CHOL-Cholesterol; TRIGLY -triglycerides

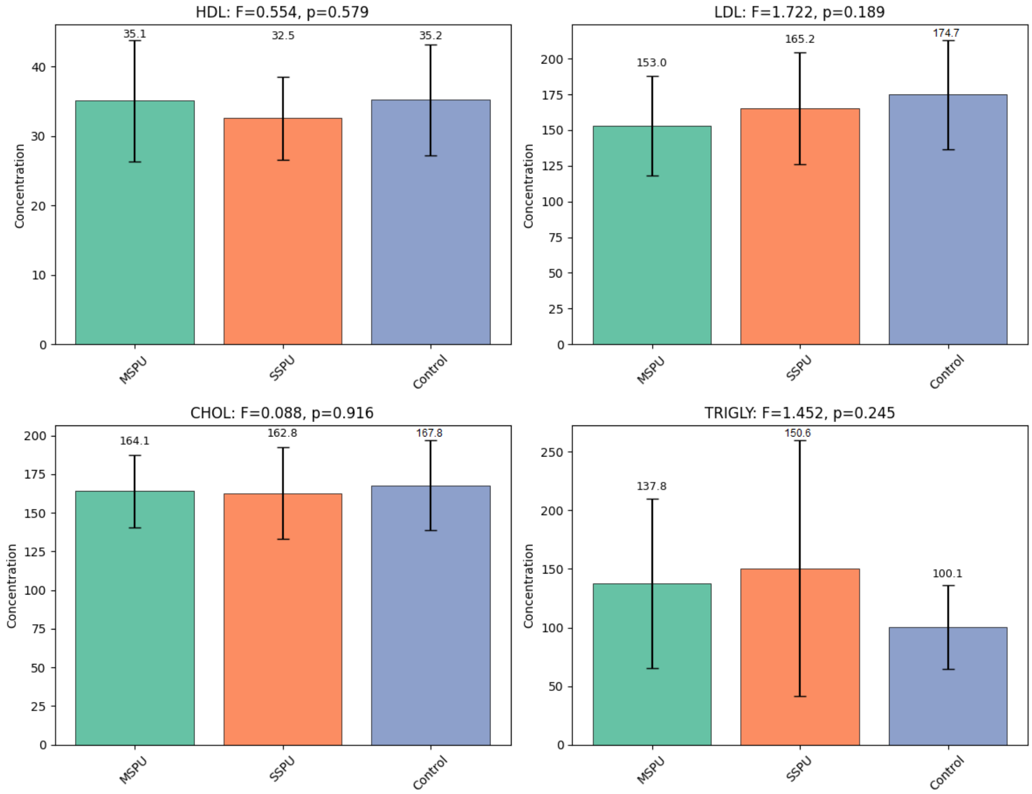

Figure 3: Group comparison on lipid profile (One Way ANOVA)

DISCUSSION

In the present single-session study involving sedentary young adults, paired t-tests showed significant within-group changes in triglycerides and total cholesterol in MSPU and control groups, and an increase in LDL in the SSPU group. However, no statistically significant differences were found between the MSPU, SSPU, and control groups for most lipid outcomes. This result suggests that acute

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soleus push up exercises may induce significantly changes in lipid profile within groups. But the magnitude of these changes may not be strong enough to differ significantly across intervention types in a single session.

The acute effects of short term on lipids are well-documented, especially on triglycerides. As these exercises enhances triglyceride clearance from the circulation due to increases muscle lipoprotein lipase activity. So even in single sessions, producing short-term TG reductions regardless of long-term training status in postprandial lipid response. The aerobic exercise decreases the rise in triglycerides after meals, due to increased Triglyceride-Rich Lipoprotein (TRL) clearance and reduced Very Low-Density Lipoprotein (VLDL) secretion from liver[8]. In many studies, triglyceride lowering occurs even with moderate or low-intensity exercise and does not require high intensity[9,10]. But a single session of soleus push-up exercises in healthy sedentary young adults led to within-group increases in triglycerides, alongside modest changes in HDL, LDL, and total cholesterol. Acute exercise performed within a few hours of a meal does not always reduce triglycerides; in fact, they can temporarily rise before exercise-induced clearance occurs[11].

On the other hand, acute changes occurred in HDL and LDL were not very clear, often requires more energy expenditure or repeated training. Meta-analyses show that chronic aerobic training modestly increases HDL and reduces LDL over weeks of regular training. But acute increase in HDL is not much consistent, and changes are smaller as compared to triglycerides[12]. Single-sessions often fail to show acute significant changes in HDL or LDL, as lipid measurements are taken only a few hours post-exercise[13]. This is consistent with the lack of significant between-group differences in HDL and LDL in the present study.

Similarly, a systematic review reported a wide range of lipid responses across different exercise types and intensities in LDL, HDL, or total cholesterol after short-term interventions[14]. Another explanation for the absence of significant between group differences is physiological variability and the acute, variable responses. Post-exercise lipid changes can be influenced by recent food intake, timing of blood sampling, and individual metabolic variability, so make group differences harder to detect the changes in a single session without tight dietary control. Even in studies with well-controlled aerobic exercise, often report mixed results for HDL and LDL immediately after[13].

Given these factors, our findings of within-group lipid changes in the absence of statistically significant between-group differences are not unexpected and underscore the importance of study duration, energy expenditure, and repeated exercise stimuli for eliciting true interventional differences in lipid profiles.

CONCLUSION

Acute soleus-focused exercises may transiently modify lipid parameters in healthy young individuals especially in triglycerides. However, no statistically significant between-group differences were observed across MSPU, SSPU, and control groups for HDL, LDL, total cholesterol, or triglycerides. So, a single exercise session is insufficient to generate differential lipid responses between varying exercise intensities. to achieve clinically meaningful and sustained improvements in lipid profiles, repeated training sessions for longer durations with patient with abnormal lipid profile are likely required.

DECLARATIONS & STATEMENTS

Author's Contribution

MB and SN: substantial contributions to the conception and design of the study.
MB, OBM and AQ: acquisition of data for the study.
MB: interpretation of data for the study.
MB: analysis of the data for the study.
MB, SN, OBM and AQ: drafted the work.
MB, SN, OBM and AQ: revised it critically for important intellectual content.
MB, SN, OBM and AQ: final approval of the version to be published and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

The study conducted in Pakistan railway general hospital from march 2024 to June 2024. Ethical approval was taken from Research Ethical Committee of Riphah College of Rehabilitation and Allied Health Sciences, Islamabad (Riphah/RCRAHS-ISB/REC/MS-PT/01819).

Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Funding Sources

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Conflicts of Interest

None to declare.

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Research Article

Association of age, BMI and physical activity with the risk of musculoskeletal injuries among school going children

Sidra Nabil[1]*, Raees Fatima[1], Adeeba Tabassum[2], Maria Javid[3], Aqsa Iqbal[1]

ABSTRACT

Background: Understanding the factors that predict risk of musculoskeletal injuries among school going children is necessary for developing timely intervention before accidents occur.

Objective: To analyse the relationship between age, BMI, physical activity and MSK injuries among school going children.

Methodology: A cross sectional analytical study was carried out on children of schools of Islamabad and Rawalpindi having sample size n=127. Male students of age between 8-12 years were included in the study. Data was collected including age, BMI and physical activity level on Physical Activity Questionnaire for Children (PAQ-C) and risk of injury with Functional Movement Screen (FMS). Data was analysed using Hierarchical Regression Analysis.

Result: A multiple regression results showed that variables were statistically non-significant and showed low explanatory power. $F(9, 90)=0.936$, $p=0.497$. in model 1 Age and BMI explain 3.7% of total variance in injury risk. And in model 2 adding physical activity increased the variance to 6.7%.

Conclusion: Only considering how old, what sex or what BMI a school-age child has does not accurately show injury risk. It did not appear that exercise was greatly protective, even though obesity seemed to lower the chance of muscle and bone injuries. Therefore, it appears that factors such as what exercise is done, someone's general health and the environment are more important in predicting injury risk.

Keywords: age; BMI; musculoskeletal injuries; physical activity.

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INTRODUCTION

Globally, musculoskeletal injuries are a significant public health issue that contribute significantly to the burden of pain and disability[1,2]. In children and adolescents, musculoskeletal complaints are prevalent. Children's physical and mental health suffers as a result of these symptoms. but little is known about their underlying causes and risk factors[3]. The most significant cause of MSK injuries on children is musculoskeletal discomfort, which restrict the mobility and result in MSK pain, psychological, and physical issues[4, 5].

In children increased body weight cause joint and spinal stress, while poor fitness, inadequate training, or postural misalignment can heighten vulnerability[6]. The overuse injuries also caused by early specialization and weight training[7]. The prolonged sitting, improper ergonomics, family history of musculoskeletal pain, and psychosocial stress may also contribute[8, 9]. Sports-related injuries in children are also common because their bodies are still growing[10]. During growth spurts, flexibility decreases and changes in bone and muscle development make them more vulnerable to strain[11].

Although children generally heal faster, the period of rapid growth creates an imbalance between strength and flexibility, increasing the risk of injury. Children with low fitness levels or limited mobility may also experience more pain and difficulty participating in physical activities, which can lead to chronic problems[12]. Body Mass Index (BMI) and physical activity are strongly linked. While BMI is often used to define weight categories, it does not reflect muscle mass or fat distribution. Regular physical activity helps maintain a healthy BMI by improving metabolism, burning calories, and supporting overall health[13,14,15].

Previous research on musculoskeletal injuries in school-age children identified a number of important gaps in the body of knowledge. Children who were not athletes in school settings did not received enough attention in the literature since most of it has been on adult or athletic groups. Furthermore, there was a dearth of thorough information on kids from particular areas, especially in low- and middle-income nations where environmental and educational circumstances differed widely. Although there is a wealth of research on paediatric MSKI worldwide, there is comparatively little thorough, region-specific data available in Pakistan, especially when it comes to school-age children and a wide range of risk factors other than merely large school bags. Thus the objective of this study was to examine associations of age, BMI, and physical activity with musculoskeletal injury risk among school-going children.

METHODOLOGY

Study Design: This study employed a cross-sectional design to conduct in private schools located in Rawalpindi and Islamabad, with data collection taking place between August and October 2024.

Participants Selection: A total of n=200 participants meeting the eligibility criteria were approached, of whom n=127 were included in the study. The study included male school-going children aged between 8 and 12 years. Participants were not actively engaged in any form of competitive sports during the study period. Children were excluded from participation if they had any mental or physical disability, a recent history of acute illness or fracture, active inflammation or infection, or any physical deformity that could interfere with the assessment or performance of physical activity.

Variables: The age, BMI and physical activity level on Physical Activity Questionnaire for Older Children (PAQ-C) were used to collect the data. The Low PAQ-C score means low physical activity and vice versa. The Functional Movement Screen (FMS) is standardise screening tool to assess the movement efficiency, including limitations, asymmetries, and dysfunctional movement patterns. In FMS, there are seven fundamental exercise tasks including deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability. A three-point Liker scale ranged from 0-3 was used to assess the movement efficiency. The zero indicate low movement quality and three mean high. The total score is 21, while ≤14 means have greater odd for sustaining an injury.

Data collection process: The data was collected during break time to ensure standard conditions for all assessments. All assessments were taken on all tools under the supervision of sports physical therapist to ensure consistent scoring. The systematic sampling technique was used to recruit the sample from n=779 students, evaluated for eligibility and out of which n=127 student full filled the criteria.

Sample Size: The sample size was calculated by G*Power 3.1.9.7, with an effect size of 0.25, a significance level (α) of 0.05, and a power (β) of 0.80. So the total sample size was n=127 participants, needed to find association between variables.

Statistical method: The demographic variables were presented as mean±SD, including age, height, weight, and BMI. While the categorical variables were presented as frequency distribution in graphs,

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such as grades/classes, BMI categories, and PAQ-C items. The assumption of the model based hierarchical regression was met, allowing further analysis. The Model 1 was included Age and BMI category to predict the ability of demographic characteristics. While in the Model 2 Physical Activity Variables the PAQ-C items from Q2-Q8, representing school-based, leisure, and organized physical activities, to assess whether physical activity contributed additional explanatory power beyond demographics. For each model, Coefficient of determination (R^2) to explained variance, F-test for overall model significance, and Unstandardized (β) coefficients with corresponding p-values to determine the significance and direction of individual predictors. Forest plot was used to visually present effect sizes and confidence intervals. A $p<0.05$ was considered statistically significant. The analysis was done by using SPSS ver 26.

Ethical consideration: Ethical approval was obtained from the research and ethical committee of Riphah College of Rehabilitation and Allied Health Sciences (Riphah/RCRAHS-ISB/REC/MS-PT/01926) and permission was granted by Principals Allied school, Islamabad. Informed consent from parents and assent from students were obtained, ensuring confidentiality and anonymity throughout the study.

RESULTS

The mean age of the n=127 participants was 10.89±1.43 years, with average height 133.54±10.55 cm, ranging from 101.0 cm to 154.2 cm. The mean Body Mass Index (BMI, was 17.60±0.62, with range from 15.98 to 19.99. The n=90(70%) of the students were from middle grades (3, 4, and 5) contributing in the study. (Figure 1-3)

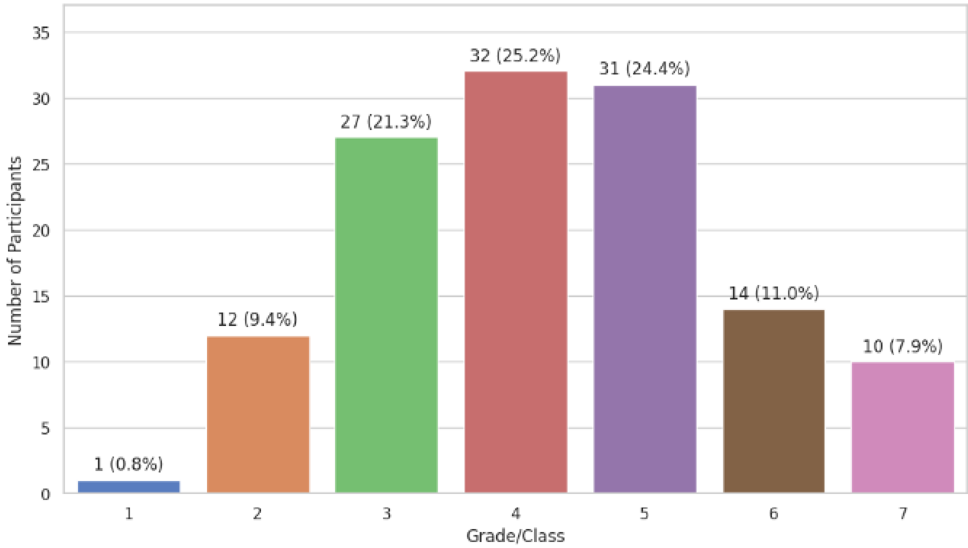

Figure 1: Frequency distribution (Grades/Classes)

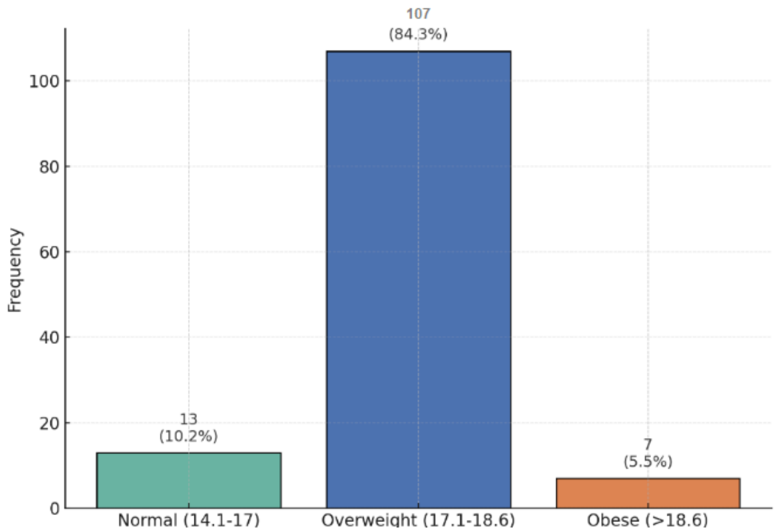

Figure 2: Frequency distribution (BMI)

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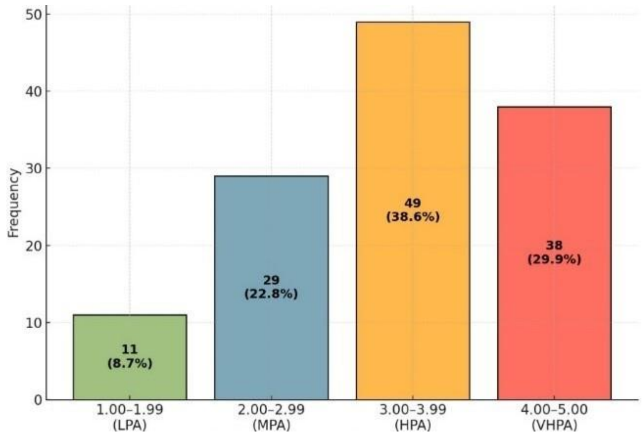

Figure 3: Frequency distribution (PAQ-C)

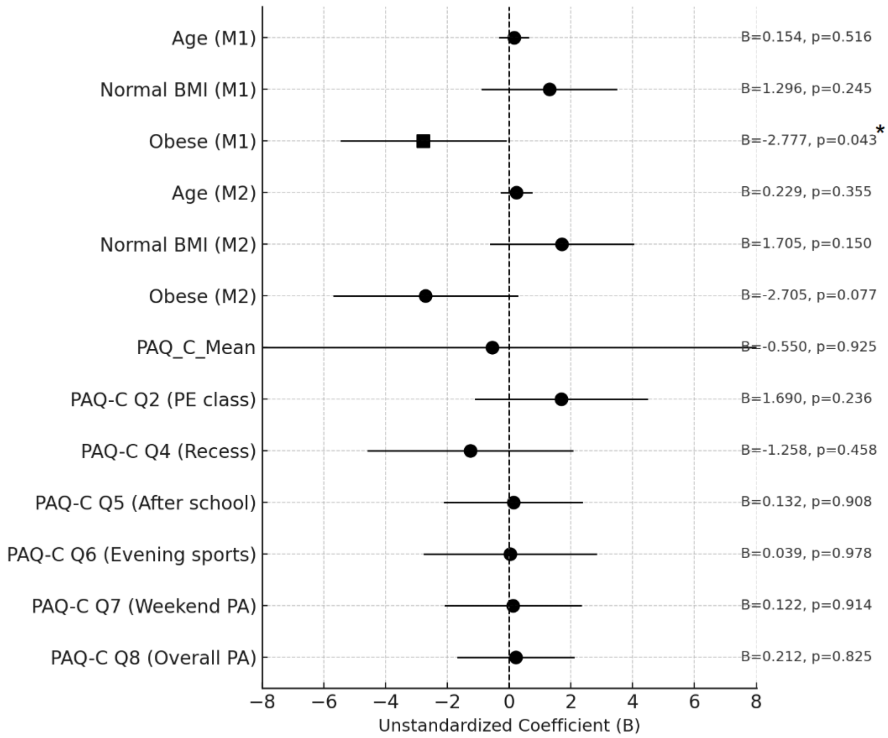

Figure 4: Forest plot of hierarchical regression analysis

The hierarchical regression analysis was structured in two sequential models: the first included demographic variables (Age and BMI), while the second introduced physical activity-related variables (PAQ-C Q2 to Q8) to assess their additional predictive power. Despite meeting assumptions, these models showed low and non-significant explanatory power and overall fit, limiting their practical predictive value.

The first model, which included only Age and BMI category, accounted for 3.7% of the variance in musculoskeletal injury risk (R^2=0.037). However, this model was not statistically significant {F(2, 97)=2.363, p=0.098}, indicating limited predictive value. In the second model, the inclusion of physical activity variables from the PAQ-C (Q2–Q8) slightly increased the explained variance to 6.7% (R^2=0.067), but the Adj. R^2 dropped to -0.005, suggesting over fitting. The overall model remained non-significant {F(9, 90)=0.936, p=0.497}, indicating that the additional predictors did not improve model performance.

The results showed that age was not a significant (p≥0.05) predictor in either model. In Model 1, being obese was associated with a significant decrease (p=0.043) in injury risk compared to the overweight reference group. In Model 2, this effect became non-significant (p=0.077), suggesting that the inclusion of PAQ-C variables diluted the BMI effect. None of the PAQ-C items were also not statistically significant (p≥0.05), but PAQ-C Q2 showed a positive trend and PAQ-C Q4 displayed a negative trend. (Figure 4)

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DISCUSSION

The objective of this study was to examine associations of age, BMI, and physical activity with musculoskeletal injury risk among school-going children. The result suggested that the age did not significantly predict injury risk in either model (p=0.221 in Model 1; p=0.194 in Model 2), though it showed a weak positive association.

According to a study on injuries connected to teenage physical activity, the incidence of injuries varied by age group, with older kids showing a reduced chance of getting hurt when engaging in leisure-time physical activities than their younger counterparts[16]. In order to promote musculoskeletal health in school-age children, research highlights the dynamic link between age and MSK injury risk and the necessity of age-appropriate preventative strategies, such as strength training, movement instruction, and safe play spaces[17].

Children's musculoskeletal systems change as they mature, resulting in changes in muscular strength, coordination, and bone density that may affect their susceptibility to injuries[18]. While physical development may play a part in injury risk, posture, habits of physical activity, and environmental variables are more important[19]. These results provide confidence to the idea that, although age may have a positive associated with the incidence of MSK injuries. Other characteristics including physical development, movement efficiency, and exposure to activities that are prone to injuries are probably more important. The body of research highlights the necessity of a multifaceted strategy for injury prevention that takes age into account in addition to physiological, biomechanical, and environmental factors[20].

The studies showed that the FMS identify asymmetries and functional movement deficits, which are frequently associated with musculoskeletal injuries. Those with higher BMIs especially those who are overweight or obese generally have lower FMS scores, which may indicate movement injuries and a higher risk of injury[21, 22]. Research has demonstrated that changes in FMS performance can forecast changes in BMI over time, supporting the notion that movement competence is essential for preserving a healthy weight[23].

Furthermore, kids with lower FMS scores typically do less exercise, which increases sedentary behaviour and may have long-term health effects [24]. The relationship between schoolchildren's BMI and levels of physical activity was examined in a research published in BMC Public Health. Children who are overweight or obese were shown to be less active, which may lead to inefficient mobility and a higher risk of injury[25]. Being overweight may increase the strain on the musculoskeletal system, leading to discomfort and potential long-term health issues[4]. In current study, the BMI is statistically significant, but it is unlikely to be the only factor influencing injury risk. The low sample size may be the reason for insignificant results.

Because BMI primarily assesses weight in relation to height rather than body composition or functional movement patterns, it may not be a good indication of injury risk on its own. Muscle mass, fat distribution, and other biomechanical characteristics that affect movement efficiency and injury risk are not taken into consideration by BMI. These findings could potentially be the consequence of methodological variances, population-specific changes, or the requirement for a multifactorial strategy that integrates screening techniques other than BMI. A more thorough knowledge of children's injury risk may be possible by taking into account different metrics such body fat percentage, mobility evaluations, and levels of physical activity[26].

This result suggests that the model's accuracy in determining the risk of musculoskeletal injuries was not significantly improved by adding PAQ-C items. The results show that, despite to improve the model by adding more variables, did not offer significant explanatory power. Numerous studies have examined the connection between children's injury risk and physical activity, with varying degrees of predictive validity[27, 28]. Although physical activity has many health advantages, there is an inherent risk of injury, especially for school-aged children, according to research published in the British Journal of Sports Medicine[29].

The school-age children's are naturally at risk for injuries when participating in physical activities. Organized sports have a higher injury incidence rate than disorganized leisure activities[30]. The significance of progressive adaptation to exercise by showing that children who have lower regular levels of physical activity are more likely to sustain injuries during physical activities[31]. Predicting injuries is difficult since physical activity isn't always a reliable indicator on its own. Injury risk is influenced by a number of factors, including individual differences, environmental factors, prior injuries, and biomechanics[32]. It shows that injury prediction models are variable and occasionally incorrect due to the lack of strong, evidence-based criteria in school sports injury prevention strategies. Given that injury patterns vary according to a child's developmental stage and degree of sports engagement, age and maturity play a significant role as well[33]. Biomechanical, physiological, environmental, and psychological factors all play a part in injuries. biomechanical, physiological,

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psychological and environmental factors collectively influence injury occurrence[34, 35].

This study has several limitations. Future studies should have a more varied sample size to increase the findings' relevance because gender and sex affect BMI, exercise levels, and injury patterns. The use of self-reported measures, such as the PAQ-C, may have introduced recall and social desirability bias. As the sample size was smaller and limited to students from selected private schools, the findings may not be generalizable to all schoolchildren.

CONCLUSION

The results of this study indicate that school-age children's injury risk cannot be accurately predicted by age, or physical activity levels alone. Consequently, methods for preventing injuries shouldn't be limited to these specific traits. Instead, to create successful preventative measures, a more thorough strategy that considers a variety of physiological and environmental aspects is required. The findings also show that the regression model's ability to adequately explain injury risk is limited, highlighting the need for more study.

DECLARATIONS & STATEMENTS

Author's Contribution

SN, MJ and AI: substantial contributions to the conception and design of the study.
RF and AT: acquisition of data for the study.
AT, MJ and AI: interpretation of data for the study.
SN, RF and AT: analysis of the data for the study.
SN, RF, AT, MJ and AI: drafted the work.
SN, RF, AT, MJ and AI: revised it critically for important intellectual content.
SN, RF, AT, MJ and AI : final approval of the version to be published and agreement to be accountable for all aspects.
of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

Ethical approval was obtained from the research and ethical committee of Riphah College of Rehabilitation and Allied Health Sciences (Riphah/RCRAHS-ISB/REC/MS-PT/01926) and permission was granted by Principals Allied school, Islamabad. Informed consent from parents and assent from students were obtained, ensuring confidentiality and anonymity throughout the study.

AI Use Statement

The authors used Grammarly to improve language clarity during manuscript preparation. Generative AI tools such as ScisSpace and Semantic Scholar were used to assist with literature summarization and refinement of the research rationale. All interpretations, conclusions, and original ideas remain solely those of the authors and approved by the authors.

Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Conflicts of Interest

None to declare.

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Research Article

Association of cognition and its impact on physical performance in female football players with a history of concussion: a cross sectional study

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ABSTRACT

Background: Cognitive skills are important in athletics, especially in football, because quick thinking, teamwork and fast reaction times are key. Concussions have different results for female athletes than for males which can result in changes in both cognitive and physical performance. Yet, there is not much information available on cognition and performance link in female football players who have had concussions.

Objective: To determine the association between cognitive function and physical performance in female football players with a history of concussion.

Methodology: This cross-sectional study included n=84 female football players aged 14–25 years. Verbal Cognition Test (VCT) for executive function, Delayed Word Recall (DWR) for working memory, Digit Backward (DB) for memory and Attention and Month in Reverse Order (MRO) for executive function were used to test cognitive function. Physical performance assessments included the Vertical Jump, Run Three, 505 Agility and 3-HOP Tests (both right and left legs). The study used a multiple regression analysis while controlling for age, BMI, amount and timing of play, number of headings during games, collisions and temporary loss of consciousness.

Result: The results show that having lesser VCT and MRO leads to poorer results in the 3-HOP Right Leg test ($p<0.05$). Practicing high-heading skills allowed athletes to complete Run Three faster ($p=0.043$). Nearly significant findings indicated that concussion history did play a moderating role in the results ($p=0.079$). For Vertical Jump, 505 Agility and 3-HOP Left Leg tests, no significant relationships were discovered.

Conclusion: The performance of female football players in lower-body power and agility is affected by cognitive functions, especially by verbal skills and reaction time.

Keywords: concussion; cognition; female football players; physical performance

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INTRODUCTION

Concussion is a mild type of traumatic brain injury with sudden blow to head[1]. Sport-related concussion is the result of a collision that affects the brain, causing a brief loss of neurological function and usually no structural damage[2]. The most frequent symptoms of sports-related concussion are severe headaches and neck pain, problems with balance, cognitive problems, sleep problems, and mental disorders[3]. Repetitive incidence of heading has been linked with the neuro inflammatory changes and minor disturbances in neural functioning that may influence memory, attention, and how the brain processes information. (Cognition)[4].

Females exhibit higher concussion rates due to anatomical differences (e.g., neck strength) and hormonal influences[5]. Post-concussion, cognitive deficits may impair reaction time and coordination[6]. Football is a high contact sport that places a lot of physiological stress on the body and needs both aerobic endurance, anaerobic power and high bursts of energy. A typical match can see players cover up to 15 kilometres and the vast majority of this movement happens at close to 70% of their VO_2 max[7].

Cognition encompasses mental processes such as perception, memory, reasoning, and problem-solving, which are critical for athletic performance[8]. In football, cognitive abilities enable players to anticipate opponents' moves, execute strategies, and adapt to dynamic game situations[9]. Jean Piaget's theory highlights that cognitive maturation, particularly abstract reasoning, enhances decision-making in sports[10]. Female football players rely on executive functions (e.g., working memory, attention) for tactical execution[11]. Cognitive process like perception & Attention essential for tracking ball movement and teammate positioning[3]. Executive functions in cognition influence agility and response inhibition in football[12]. Social cognition facilitates teamwork and emotional regulation[13].

The available research showed that female athletes may experience concussions differently as compared to male, with higher susceptibility, more severe symptoms, and prolonged recovery. Gender based differences including neck muscle strength, hormonal changes, biomechanics, and symptom reporting, may further affect the relationship between cognition and physical performance. Despite increasing number of female footballers, gender specific research on concussion is limited. This study was aimed to investigate the impact of cognitive function on physical performance in female players with concussion history.

METHODOLOGY

Study design: Cross-sectional study conducted at Pakistan Sports Complex Islamabad, Pakistan Sports Complex Peshawar and football clubs (2024-2025). This study was approved by the Pakistan Sports Board(PSB-Pesh/July/30-1). It was carried out according to the principles stated in the Declaration of Helsinki with informed consent was obtained from participants.

Participants: Participants included were active female footballers, aged 14–25 and either have no history of concussion or have experienced one in the past 1 month, participating in practices or games that involve frequent heading. The criteria for exclusion were recent Musculo-skeletal injuries, concussion not linked to sports, diagnosed neurological/psychiatric disorders, malignancies and substance abuse. A non-probability convenience sampling technique was used for sample collection.

Outcome measures: To predict the association between cognitive function and physical performance in female football players with a history of concussion by using a structured questionnaire having demographics, Cantu grading system for concussion[14], and SCOAT-6[15]. Physical performance was evaluated through the Vertical Jump (explosive power), Run Three (acceleration and speed), 505 Agility (change-of-direction ability), and 3-HOP Test (unilateral leg power). Cognitive function was assessed using four standardized tests: the Verbal Cognition Test (VCT) for language processing, Delayed Word Recall (DWR) for memory, Digit Backward (DB) for working memory, and Month in Reverse Order (MRO) for reaction time and executive function by SCOAT-6. Covariates included age, body mass index (BMI), daily playtime (hours), and heading frequency (ball impacts per session) to control for confounding factors.

Sample size: A total of n=99 participants were required as calculated through G*Power version 3.1.9.7, keeping effect size medium (f^2=0.15), α error probability at 0.05, and power (1-β) at 0.90 with 3 predictors. A total of N=99 female football players were screened for eligibility, with n=84 meeting inclusion criteria and completing the study protocol. The final sample had a mean age of 18.4±2.1 years, with 11 participants (13.1%) reporting a history of concussion.

Statistical methods: The data was presented using tables and graphs, where continuous variables showed mean±SD and categorical variables showed numbers and percentages. Multiple linear regression was carried out to explore the relationship between mental and physical tests (VCT, DWR, DB, MRO; Vertical Jump, Run Three, 505

Agility and 3-HOP). Concussion history (Yes/No) was considered as a moderator variable to investigate for interactions. The variables age (years), BMI (kg/m²) and playtime in hours per week were treated as continuous, while heading frequency, history of head collisions and episodes of losing consciousness were treated as categorical. All analyses were done using SPSS version 26 and results were considered statistically significant if $p<0.05$.

RESULTS

In this study, the performance of cognitive and performance was examined in 84 female football players (mean age 18.4 ± 2.1). The important outcomes are being discussed. A multiple linear regression analysis used to find the association of cognition and physical performance with history of concussion as moderator. The concussion history did not significantly moderate cognition-physical performance relationships ($p > 0.05$), a trend-level interaction was noted for the 3-HOP Right Leg (Concu_VCT: β=0.126, p=0.079)

The explained variance was low across tests, with R^2 ranging from 0.036 for Vertical Jump to 0.189 for the 3-Hop Test (Right/Left average), indicating that most predictors accounted for a small proportion of performance variability. Verbal Cognition Total (VCT) had a significant negative effect on right-leg 3-Hop Test performance (β=-0.048, p=0.027). The left-leg 3-Hop Test showed a similar trend (β=-0.023, p=0.470), leading to a mean β=-0.036, p=0.249. Month in Reverse Order (MRO) also showed a significant negative association with the right-leg 3-Hop Test (β=-0.013, p=0.004), with the left-leg showing a non-significant trend, producing a mean β=-0.011, p=0.085. While other cognitive measures (Delayed Word Recall, Digit Backward) did not significantly predict performance. The Heading frequency was significantly associated with Run Three Test performance (β=-0.121, p=0.043), suggesting a small negative effect of heading frequency on running agility. The Concussion history, head collision frequency, loss of consciousness, age, BMI, and playtime did not significantly predict performance across any test, although concussion history showed a non-significant trend toward lower 3-Hop Test scores (mean β=-2.04, p=0.263). (table 1)

Table 1. Physical Performance with Cognitive, Demographic, and Head Injury Predictors

Model / Predictor	Vertical Jump	Run Three Test	5-0-5 Agility Test	3-Hop Test (Right/Left mean)
R^2	0.036	0.049	0.077	0.189
Adjusted R^2	−0.026	0.012	0.018	-
p-value	*0.715*	*0.546*	*0.269*	*0.052*
Cognition only (1)	-	-	-	-
Verbal Cognition Total (VCT)	β=0.126, p=0.378	β=0.042, p=0.577	β=−0.010, p=0.783	β=−0.036, p=0.249
Delayed Word Recall (DWR)	β=−0.079, p=0.803	β=0.274, p=0.101	β=0.032, p=0.702	β=−0.049, p=0.510
Month in Reverse Order (MRO)	β=−0.026, p=0.402	β=0.011, p=0.495	β=−0.004, p=0.607	β=−0.011, p=0.085
Digit Backward (DB)	β=−0.402, p=0.391	β=0.006, p=0.982	β=0.119, p=0.335	β=−0.033, p=0.491
Cognition × Concussion (2)	-	-	-	-
Concussion × VCT	β=−0.129, p=0.787	β=0.185, p=0.459	β=0.132, p=0.293	β=0.124, p=0.244
Demographics (3)	-	-	-	-
Age (years)	β=0.015, p=0.614	β=−0.071, p=0.508	β=−0.041, p=0.452	β=0.011, p=0.803
BMI (kg/m²)	β=−0.029, p=0.325	β=0.013, p=0.901	β=0.010, p=0.842	β=−0.007, p=0.868
Playtime (hours/day)	β=−0.057, p=0.614	β=−0.289, p=0.470	β=−0.091, p=0.652	β=−0.047, p=0.777
Heading exposure (4)	-	-	-	-
Heading frequency	β=−0.046, p=0.680	β=−0.121, p=0.043*	β=0.002, p=0.937	β=0.011, p=0.662
Head injury severity (5)	-	-	-	-
Concussion history (Yes)	β=3.173, p=0.749	β=−6.196, p=0.236	β=−4.325, p=0.101	β=−2.04, p=0.263
Head collision frequency	β=−0.103, p=0.667	β=−0.393, p=0.642	β=−0.140, p=0.742	β=−0.176, p=0.616
Loss of consciousness	β=−0.155, p=0.849	β=2.738, p=0.340	β=1.366, p=0.342	β=−0.533, p=0.654

Significance level- p<0.05, p<0.01** * p<0.001**

R^2-proportion of variance in the dependent variable explained by the regression model; Adjusted R^2- the number of predictors and adjusts R^2 for model complexity; β -is the unstandardized regression; VCT-Verbal Cognition Total ; DWR -Delayed Word Recall ; MRO- Month in Reverse Order ; DB -Digit Backward

DISCUSSION

The result of recent study revealed that concussion history showed a trend toward significance but was not a strong moderator of the cognition-performance link.

A study from literature by McGroarty et al. (2020) said that although many female athletes appear to have characteristic symptoms following a concussion, they often end up with results similar to those who did not get a concussion[6]. Although concussions were not a key part in recent study results, they still appear to have some micro effects. It is clear from studies in literature that female athletes may not handle cognitive difficulties after concussion as well as male athletes, though they are better at recovering with more adjustments or a longer rehab process[16,17]. There might not be a strong moderating effect because of this study sample reflects a well-done recovery or there isn't enough data. However, it points out that everyone

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requires an individualized evaluation of cognitive-physical functioning after a concussion[18].

The current result showed link with poor verbal cognition was associated with poorer performance in the 3 HOP Right test moderated by concussion history, indicating that athletes with weaker executive verbal function struggled more in lateral dynamic tasks. The result from recent study in line with the result of a study which concluded that the cognitive skills of verbal fluency and flexibility of thinking helped predict how individuals would do physical performance test in elite football[16].

The current study result get support by a retrospective study by Baillargeon et al. adolescents have continuing neurophysiological impairments after concussion, likely because of the continued development of the frontal lobes, which influences the working memory and executive functioning[17]. A study related to concussion also showed balance problem by cognitive deficit[19]. So, the result of recent and previous study proves that verbal thought processes, belonging to executive function, are very important for dynamic body movements. Lack of verbal fluency can suggest problems with both processing information and controlling attention which makes it hard for athletes to respond to abrupt spatial changes in power-based sports[20].

As female players may notice this connection between working memory flexibility and gameplay challenges more clearly because of differences in how they are mentally engaged. So, these finding highlights why neurocognitive tests are so important in sports performance and injury prevention[21,22]. The significant relationship is found between MRO and 3 HOP Right performance in this study in concussed athletes. This tells that athlete who performed poorly in the MRO task tended to have weaker lower-limb outcomes. According to literature by Höfflin et al. (2021) result also support the result of study that slower handling of tasks and less efficient mental processing in dual tasks were connected to lower jump and agility test results in female athletes[17].

The mechanism of MRO task requires people to use their memory and attention in order to control difficult body movements. Any reduction in cognitive flexibility can hinder an athlete's ability to quickly interpret and use the information they get from proprioception and space when making explosive movements[23]. The findings confirm that performing neuromechanical coordination in difficulty lower-body movements depends partially on attention from the brain. It is especially important after a concussion because some testing may not detect changes in working memory[24].

The recent study result show that more frequent heading is significantly associated with better scores in the Run Three Test, indicating enhanced speed and agility in athletes with concussion. The result have support from previous study by Hermsdörfer et al. showed that there were no serious short-term harms to cognition or sensorimotor skills from heading for semi-professional female soccer players[25]. Another study concluded; players who often head the ball might have better neck strength, coordination and conditioning for their sport, leading to improved sprinting ability[26]. While these findings are a challenge to the belief of universal harm caused by frequent heading. So, there should be cautious, because repeated heading can result in long-term decline in mental functioning, according to literature[27]. It makes us wonder how severe the impact of heading can be and suggests looking further into different exposure limits for men and women.

The current result showed that no significant association found between cognitive test performance or concussion history and t physical performance tests(505 Agility Test, VJT.3HOPL) This current result can be proven by previous literature Krenn et. al. (2022) result showing that executive functions(cognition) do not matter as much for simple, straight movements which instead rely more on physical skills[28]. These result from current study and literature can be proven with this mechanism that some physical test results do not change much with different levels of cognitive ability. Because of the strict rules, these movements depend on strong muscles and technique, not so much on what the mind can do[29].

The result from current study for better performance in pressure-demanding dual-tasks is linked with superior cognitive scores, particularly in executive and attentional domains. According to literature, athletes who possess higher cognitive abilities and can keep their cool often do better in tasks where they need to make quick, tough decisions[30] .

These results get support by mechanism of response inhibition, working memory and cognitive flexibility are seen as key abilities in high-pressure settings. In football for women, because the action is fast and challenging, these mental strengths tend to be important when things matter most. It backs the addition of cognitive drills (pressure situations) to training in sports and supports the rise of cognitive readiness in scientific approaches to performance[30].

The sample size was relatively small only 11 participants reporting a recent history of concussion (13.1%), reducing the statistical power to detect moderation effects of concussion on cognition-performance relationships. Furthermore, the study only considered recent concussions within one month and did not assess cumulative or historical concussions, which may have long-term neurocognitive or physical performance effects.

CONCLUSION

It is concluded that although concussion history did not show a significant impact on relation between cognition and physical performance in female football players. But verbal cognition and reaction time played a big role in predicting their lower-body power showed a significant association. Future investigations should use long-term designs and images of the brain to better understand cognitive problems after concussions.

DECLARATIONS & STATEMENTS

Author's Contribution

SK, FA and A: substantial contributions to the conception and design of the study.
SK, RM, FA and MH: acquisition of data for the study.
SK: interpretation of data for the study.
SK, SK, and RM: analysis of the data for the study.
SK, SK, RM, FA, A and MH: drafted the work.
SK, SK, RM, FA, A and MH: revised it critically for important intellectual content.
SK, SK, RM, FA, A and MH: final approval of the version to be published and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

Cross-sectional study conducted at Pakistan Sports Complex Islamabad, Pakistan Sports Complex Peshawar and football clubs (2024-2025). This study was approved by the Pakistan Sports Board(PSB-Pesh/July/30-1).

AI Use Statement

The authors used Grammarly to improve language clarity during manuscript preparation. Generative AI tools such as ScisSpace and Semantic Scholar were used to assist with literature summarization and refinement of the research rationale. All interpretations, conclusions, and original ideas remain solely those of the authors and approved by the authors.

Consent Statement

Written informed consent was obtained from all participants prior to study participation. Permission for publication of the data was obtained, and confidentiality was strictly maintained.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Conflicts of Interest

None to declare.

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Research Article

Effects of soleus push-ups on lipid profile among young population

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Abstract

Background: Recent interest has emerged in soleus push-ups, due to the unique physiological characteristics to sustain prolonged activity. These exercises can be performed with minimal equipment, and may offer a practical alternative for sedentary individuals for acute lipid profile responses.

Objective: To evaluate the effects of moderate intensity and sustained soleus pushups on lipid profile level in sedentary young adults.

Method: A randomized controlled trail was conducted on n=33 sedentary healthy young, aged 18 to 35 years. Participants were placed into three groups: Group A did moderate-intensity soleus pushups, Group B did continuous soleus push-ups, and Group C served as a control group. The primary outcome measure was the change in lipid profile, including high-density lipoprotein, lower cholesterol, total cholesterol and triglycerides was gathered at baseline and after 4.5 hours of intervention.

Results: Within-group analysis revealed significant changes in lipid profiles. In MSPU, HDL (p=0.028), total cholesterol (p=0.024), and triglycerides (p=0.005) increased, while LDL was unchanged. SSPU showed reduced LDL (p=0.013) and increased triglycerides (p=0.005). Control group had increases in HDL (p=0.020), total cholesterol (p=0.010), and triglycerides (p=0.010), with non-significant LDL changes. Between-group differences were non-significant (p≥0.05).

Conclusion: The findings reveal that moderate and continuous push-ups have varied impacts on sedentary youth's lipid profile. Although HDL, triglycerides, and total cholesterol levels varied considerably across groups, LDL levels did not. Triglyceride levels changed significantly at baseline and four hours after the intervention. These findings emphasize the need of examining various attempts to promote lipid metabolic alterations in isolated individuals.

Keywords: High Density Lipoproteins (HDL), Lipid Profile, Low Density Lipoproteins (LDL), Moderate intensity exercise, Physical activity, Short duration exercise, Soleus push-ups, Sustained exercise, Triglycerides, Young population.

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INTRODUCTION

The lipid profile with elevated triglycerides, low high-density lipoprotein cholesterol (HDL-C), and abnormal low-density lipoprotein cholesterol (LDL-C), is increasingly prevalent among young adults due to sedentary lifestyles, low physical activity and prolonged sitting[1]. Early alterations in lipid profile during youth are clinically significant, as they contribute to the early development of atherosclerosis and increase the long-term risk of cardiovascular and metabolic diseases[2].

The effects of exercise has been shown to induce desirable changes in plasma lipid levels, particularly an increase in high-density lipoprotein (HDL) and a decrease in triglycerides (TG)[3]. Endurance training (ET) offers metabolic benefits, including improved lipid profiles, body fat, and blood sugar control[4]. Physical activity is a well-established conservative management to improve lipid metabolism. However, moderate-to-vigorous aerobic activities are often emphasized[3]. These activities are usually difficult to adopt or sustain among young individuals due to time restraints, low motivation, or predominantly sedentary routines. Consequently, localized, low-threshold exercises are gaining interest, as can be frequently perform with minimal equipment[5,6]. Despite convincing evidence, challenges remain in the feasibility and accessibility of regular exercise.

Soleus push-ups, targeting the soleus muscle, improve oxygen consumption, blood sugar levels, and triglycerides. Sustained soleus push-ups involve prolonged, high-intensity contractions, enhancing endurance and stability, while moderate soleus push-ups are shorter and lower intensity, enhancing strength and flexibility[7]. This study compares moderate and sustained soleus push-ups, each exerting unique physiological impacts. By evaluating the effects of these exercises on lipid profiles among young people, this research aims to establish soleus push-ups as a practical, low-cost strategy to improve metabolic health and reduce cardiovascular risks among young populations globally. This research fills critical gaps in understanding the acute impacts of soleus push-ups on lipid levels, providing insights into preventive health measures for chronic metabolic diseases.

METHODOLGY

Study design: A single blinded, crossover, randomized clinical trial was initiated after getting approval from the Research Ethic Committee (Riphah/RCRAHS-ISB/REC/MS-PT/01819) of Riphah International University, Islamabad. The study was conducted at Pakistan Railway General Hospital from March 2024 To June 2024. The purpose of the study was explained to the subjects and written informed consent in accordance with Deceleration of Helsinki was obtained.

Selection criteria: A non-probability convenient sampling technique was employed for sample collection, focusing on participants who met specific inclusion criteria: adults aged 18-35, healthy BMI, gender equality, and a sedentary lifestyle. Exclusion criteria was individuals with a history of metabolic disorders, recent fractures, lower-limb injuries, knee injuries, those following a prescribed diet and exercise routine, any congenital abnormalities, deep vein thrombosis (DVT), lower limb amputations, or diagnosed hyperlipidaemia. Participants not meeting these criteria were excluded from the study.

Sample size: The total sample size was calculated by G-power. This study would contain a total of 33 participants, divided into two groups of 11 each. The effect size is 0.25, the alpha error probability is 0.05, and the power is 0.85. A total of n=33 participant was then randomly divided into three groups A (n=11), group B (n=11) and control group (n=11).

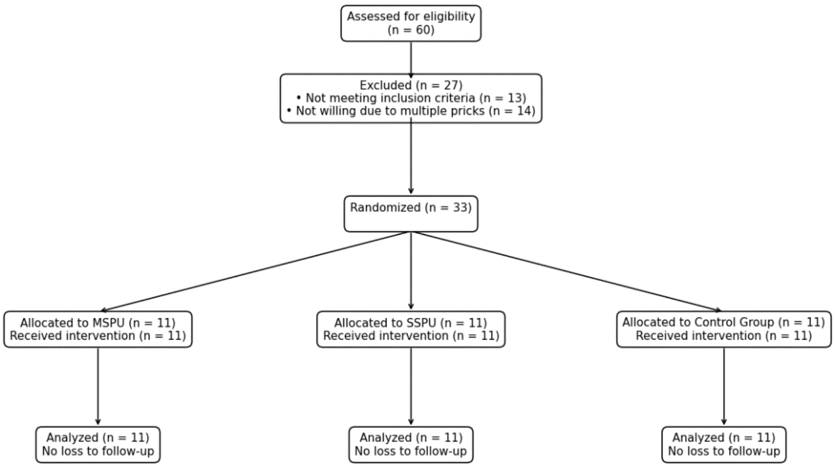

Figure 1: Consort Diagram

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Randomization: To avoid selection bias and allow for group comparisons, individuals were assigned to one of three groups using random allocation software 2.0. Each participant was given a unique identification, and a random list was created to divide them into three groups: mid-soleus push-up (MSPU), sustained soleus push-up (SSPU), and control. The deployment order remains concealed until the intervention is deployed. Participants learned about group assignments only after the baseline exam was finished. The randomization list was kept hidden from the study coordinators, who assigned participants in sealed opaque envelopes following a specified methodology.

Intervention: The intervention detail was explained to subjects and none of the participants were harmed during the study. Participants were divided into three groups for the study. The intervention group, Group A, performed moderate soleus push-ups with resistance until they reached their maximum heart rate (MHR). Group B conducted sustained soleus push-ups for up to 270 minutes. While the control group did not received any intervention. This design aimed to compare the effects of different durations and intensities of soleus push-ups on participants. These all exercises were performed by the participants actively under supervision after being demonstrated by the therapist, inside the physiotherapy OPD Pakistan Railway General Hospital. (Table 1)

Table 1: Intervention Protocol

Group A (MSPU)	Group B (SSPU)	Group C (Control)
Participants started soleus push-ups in sitting positions. To do so, the participants were seated position, the legs were at 90 degrees to the floor, feet placed flat on the ground. Participants then moved their heels up and down continuously. Soleus push-ups performed with moderate intensity using weights placed on their laps. The weight was calculated from 1RM of 30-40% of soleus muscle's strength for time till muscle fatigued.	Participants started soleus push-ups in sitting. To do so, the participants were in a seated position, the legs were at 90 degrees to the floor, and feet were placed flat on the ground. Participants then move their heels up and down continuously. Sustained soleus push-ups performed without any resistance, light intensity for up to 4.5 hours. Participants were provided with a maximum 4-minute break time after every 90-minute intervention.	No intervention

Data Collection Procedure: The purpose of the study explained to the participants. Written informed consent taken. All participants have had the same breakfast, and after 30 minutes of the breakfast, baseline data of lipid profile was taken. The participant then performed soleus push-ups as mentioned in table 1. The second sample for lipid profile was obtained after 4.5 hours. The blood sample was collected by qualified lab technologist.

Outcome Measures: The primary outcome measure of this study is the lipid profile, comprising total cholesterol (TC), HDL cholesterol (good cholesterol), LDL cholesterol (bad cholesterol), and triglycerides. These components are crucial indicators of cardiovascular health and metabolic function.

Statistical methods: For within group changes after 4.5 hours, the paired sample test was used. While for group differences One-way ANOVA test was used. The level of significance was set at $p<0.05$ and SPSS version 2 was used to analyse the data.

RESULTS

The mean age of participants as 23.88±2.42 (min 18 and max 35) years. While the BMI ranges from 22.13 to 23.01, with a mean of 23.36±4.91. All descriptive statistics are based on a valid sample of n=33 individuals.

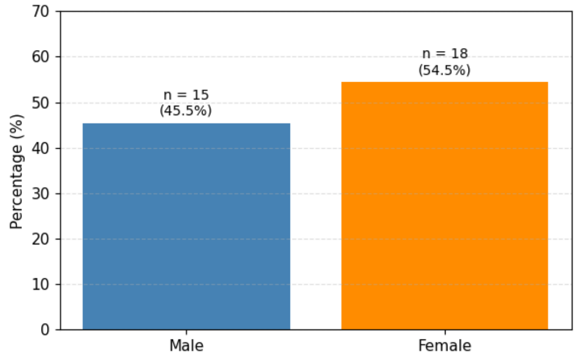

Figure 2: Gender

The paired sample t-test analysis showed different patterns of lipid profile changes across the three groups from pre- to post-intervention. In the MSPU group, statistically significant increases were observed in HDL (p=0.028, d=-0.586), total cholesterol (p=0.024, d=-0.607), and triglycerides (p=0.005, d=-0.786), while LDL showed no meaningful change (p=0.820). The SSPU group demonstrated a unique and favorable significant reduction in LDL (p=0.013, d=0.709) alongside a highly significant increase in triglycerides (p=0.005, d=-0.833), with HDL and total cholesterol showing non-significant increases (p≥0.05). The Control group exhibited significant increases in HDL (p=0.020, d=-0.627), total cholesterol (p=0.010, d=-0.710), and triglycerides (p=0.010, d=-0.711), with LDL showing a non-significant (p=0.056) increase. (table 2) One-way ANOVAs showed no significant (p≥0.05) between-group differences for HDL, LDL, total cholesterol, or triglycerides. (Figure 3)

Table 2: Pre-post Results lipid profile

Group	Lipid Marker	Pre	Post	MD	p-value	Cohen's d
		Mean±SD	Mean±SD			
MSPU	HDL	33.80±8.01	35.07±8.75	-1.27	0.028*	-0.586
	LDL	152.13±39.88	152.99±34.89	-0.86	0.820	-0.056
	CHOL	157.18±21.21	164.12±23.43	-6.94	0.024*	-0.607
	TRIGLY	96.41±31.30	137.76±72.26	-41.35	0.005*	-0.786
SSPU	HDL	31.96±5.56	32.55±5.96	-0.59	0.176	-0.355
	LDL	173.84±35.15	165.21±38.95	8.63	0.013*	0.709
	CHOL	159.81±27.81	162.75±29.80	-2.94	0.176	-0.355
	TRIGLY	89.69±43.94	150.56±109.07	-60.88	0.005**	-0.833
Control	HDL	33.25±6.55	35.20±7.97	-1.95	0.020*	-0.627
	LDL	169.18±39.08	174.71±38.33	-5.53	0.056	-0.499
	CHOL	161.24±28.82	167.76±29.04	-6.53	0.010*	-0.710
	TRIGLY	82.18±34.51	100.12±35.68	-17.94	0.010*	-0.711

Statistical significance- p<0.05p<0.05
Cohen's d- effect size- small (-0.2); medium (-0.5); large (-0.8); MSPU- mid-soleus push-up; SSPU- sustained soleus push-up; HDL-High-Density Lipoprotein; LDL-Low-Density Lipoprotein; CHOL-Cholesterol; TRIGLY -triglycerides

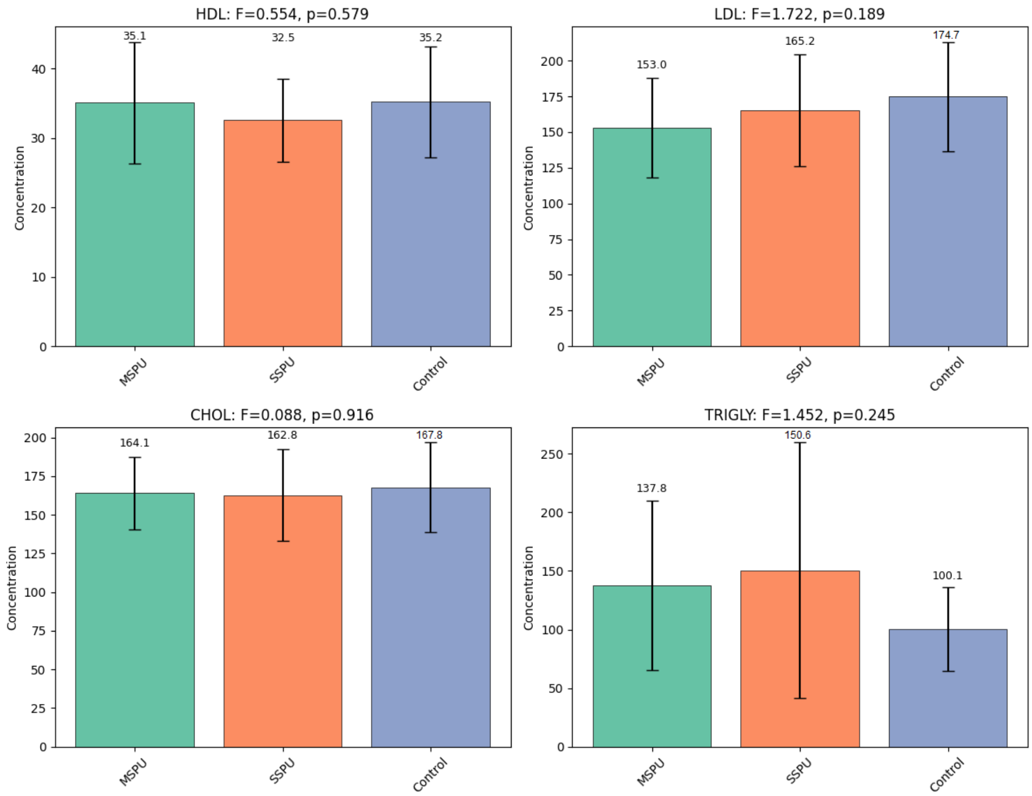

Figure 3: Group comparison on lipid profile (One Way ANOVA)

DISCUSSION

In the present single-session study involving sedentary young adults, paired t-tests showed significant within-group changes in triglycerides and total cholesterol in MSPU and control groups, and an increase in LDL in the SSPU group. However, no statistically significant differences were found between the MSPU, SSPU, and control groups for most lipid outcomes. This result suggests that acute soleus push up exercises may induce significantly changes in lipid profile within groups. But the magnitude of these changes may not be strong enough to differ significantly across intervention types in a single session.

The acute effects of short term on lipids are well-documented, especially on triglycerides. As these exercises enhances triglyceride clearance from the circulation due to increases muscle lipoprotein lipase activity. So even in single sessions, producing short-term TG reductions regardless of long-term training status in postprandial lipid response. The aerobic exercise decreases the rise in triglycerides after meals, due to increased Triglyceride-Rich Lipoprotein (TRL) clearance and reduced Very Low-Density Lipoprotein (VLDL) secretion from liver[8]. In many studies, triglyceride lowering occurs even with moderate or low-intensity exercise and does not require high intensity[9,10]. But a single session of soleus push-up exercises in healthy sedentary young adults led to within-group increases in triglycerides, alongside modest changes in HDL, LDL, and total cholesterol. Acute exercise performed within a few hours of a meal does not always reduce triglycerides; in fact, they can temporarily rise before exercise-induced clearance occurs[11].

On the other hand, acute changes occurred in HDL and LDL were not very clear, often requires more energy expenditure or repeated training. Meta-analyses show that chronic aerobic training modestly increases HDL and reduces LDL over weeks of regular training. But acute increase in HDL is not much consistent, and changes are smaller as compared to triglycerides[12]. Single-sessions often fail to show acute significant changes in HDL or LDL, as lipid measurements are taken only a few hours post-exercise[13]. This is consistent with the lack of significant between-group differences in HDL and LDL in the present study.

Similarly, a systematic review reported a wide range of lipid responses across different exercise types and intensities in LDL, HDL, or total cholesterol after short-term interventions[14]. Another explanation for the absence of significant between group differences is physiological variability and the acute, variable responses. Post-exercise lipid changes can be influenced by recent food intake, timing of blood sampling, and individual metabolic variability, so make group differences harder to detect the changes in a single session without tight dietary control. Even in studies with well-controlled aerobic exercise, often report mixed results for HDL and LDL immediately after[13].

Given these factors, our findings of within-group lipid changes in the absence of statistically significant between-group differences are not unexpected and underscore the importance of study duration, energy expenditure, and repeated exercise stimuli for eliciting true interventional differences in lipid profiles.

CONCLUSION

Acute soleus-focused exercises may transiently modify lipid parameters in healthy young individuals especially in triglycerides. However, no statistically significant between-group differences were observed across MSPU, SSPU, and control groups for HDL, LDL, total cholesterol, or triglycerides. So, a single exercise session is insufficient to generate differential lipid responses between varying exercise intensities. to achieve clinically meaningful and sustained improvements in lipid profiles, repeated training sessions for longer durations with patient with abnormal lipid profile are likely required.

DECLARATIONS & STATEMENTS

Author's Contribution

MB and SN: substantial contributions to the conception and design of the study.
MB, OBM and AQ: acquisition of data for the study.
MB: interpretation of data for the study.
MB: analysis of the data for the study.
MB, SN, OBM and AQ: drafted the work.
MB, SN, OBM and AQ: revised it critically for important intellectual content.
MB, SN, OBM and AQ: final approval of the version to be published and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

The study conducted in Pakistan railway general hospital from march 2024 to June 2024. Ethical approval was taken from Research Ethical Committee of Riphah College of Rehabilitation and Allied Health Sciences, Islamabad (Riphah/RCRAHS-ISB/REC/MS-PT/01819).

Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Funding Sources

None to declare.

Conflicts of Interest

None to declare.

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