Original Research

Effects of Physical Exercise on Cognitive Abilities: A Study of Undergraduates

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Abstract

Background: In higher education, the correlation between academic performance and cognitive abilities is well established. Physical Exercise (PE) plays a crucial role in enhancing academic achievements. However, the decline in Physical Activity (PA) among university students poses concerns regarding cognitive development and academic success.

General Objective: The present study aimed to determine the impact of a 6-week physical exercise program on cognitive domains and handgrip strength among undergraduate students at the Faculty of Allied Health Sciences.

Methods: A randomized control trial was conducted with a sample of 74 undergraduates from the Faculty of Allied Health Sciences at the University of Peradeniya, who were randomly assigned to exercise and control groups (37 per group). Information on demographic data, cognitive abilities assessed via the Montreal Cognitive Assessment, and hand grip strength measurements was gathered before and after the 6-week strengthening exercise program. Rigorous statistical analyses, including the paired and independent sample t-tests, were used to compare pre- and post-exercise measurements and between-group comparisons, respectively. The significance level was set at $p < 0.05$.

Results: Significant improvements were observed in the dominant and non-dominant grip strengths of the exercise groups. Noteworthy gains were evident in executive functioning, naming ability, language skills, delayed recall, and orientation. Conversely, the control group exhibited minimal changes, with slight improvements in delayed recall and total cognitive scores.

Conclusion: The exercise intervention led to substantial improvements in handgrip strength and various cognitive domains, notably executive function, naming abilities, language skills, delayed recall, and orientation, within the exercise group. By contrast, the control group displayed limited changes, emphasizing the efficacy of the exercise program. These outcomes emphasize the importance of structured exercise for enhancing the cognitive health of university students.

Keywords: Academic Performance (AP); Cognitive Abilities; Physical Exercise (PE); Undergraduate Students

Background

In higher education, academic success relies heavily on cognitive abilities, with Physical Exercise (PE) playing a significant role in improving Academic Performance (AP) [1]. However, when students transition to university, they often become less physically active due to academic overload and inefficient leisure time, which can negatively impact their cognitive abilities and academic success [1,2]. It is essential to find a balance between academic demands and physical activity to promote optimal cognitive development [1,3].

Physical Activity (PA), which includes any bodily movement beyond resting, is recommended by the World Health Organization (WHO) for both mental and physical health [4,5]. Research has shown that PA has a significant positive impact on cognitive functions such as memory and attention [6,7]. PE, as a structured form of PA, is particularly effective in conditioning various aspects of the body [8].

AP, which measures educational achievement, depends on cognitive abilities that are crucial for effective learning [9,11]. Evidence suggests that cognitive abilities positively influence AP [6,7]. PE has been found to positively impact cognitive abilities, suggesting that an active lifestyle is essential for cognitive health [12]. Molecular events associated with exercise, especially within the hippocampus, affect cognition, with factors such as brain-derived neurotrophic factor (BDNF) playing a key role [12]. Additionally, PA has been well documented to improve attention, cognitive function, memory, and executive function [6,13].

Despite the benefits observed in structured exercise programs in schools, there is a lack of research focusing on university students, highlighting the need to promote physical activity in this demographic [14,16]. The effectiveness of exercise programs on cognitive abilities in young adults depends on factors such as exercise intensity, type, duration, and frequency, with strength-training exercises being particularly beneficial for health and cognition [6,17,18]. Assessment tools such as the Montreal Cognitive Assessment (MoCA) and Handgrip Strength (HGS) provide insights into cognitive abilities and their relationship with physical strength in young adults [19-27].

As a justification for our research, the prevalent assessment of AP in higher education is predominantly reliant on examinations. Cognitive domains encompassing memory, cognition, attention, and concentration are crucial for achieving commendable scores on examinations and showcasing superior AP in higher education [1,2]. Prior research has underscored the affirmative relationship between PA and health, attention, and cognition [1-3].

Moreover, substantial evidence supports a positive correlation between PA and cognitive faculties [2,3]. The assessment of cognitive faculties involves the functioning of cognitive domains such as attention, memory, and concentration. Indirect gauging using grip strength also contributed to the evaluation. However, existing evidence predominantly emanates from cross-sectional studies and self-reported PA measures. Additionally, PA and physical education have witnessed a decline among university undergraduates due to multifaceted individual, social, and environmental factors during their tenure at the university [6,7]. Interventional endeavors in educational settings have shown that exercise programs can elevate cognitive performance, especially in the attention and executive function domains. Nevertheless, intervention-based studies on university students are scarce.

Therefore, it is imperative to discern the impact of PE on cognitive faculties. This study aimed to evaluate the influence of PE on the cognitive abilities and HGS of undergraduate students pursuing Allied Health Sciences. The researchers aimed to scrutinize the impact of PE during the initial phase of undergraduate studies, enabling an analysis of its effects and facilitating immediate measures to enhance cognitive abilities among undergraduates. The transition of undergraduates into the university system during their first year, involving a shift from their native language to English, may have affected their responsiveness to the cognitive assessment tools used in the questionnaire. Additionally, considering the curriculum schedule of the Faculty of Allied Health Sciences, nursing and physiotherapy undergraduates embarked on clinical training during the second year second semester. Consequently, the researchers opted to conduct the study among undergraduates enrolled in the second year, the first semester, to capture a crucial period in their academic journey.

Objectives

To compare the effectiveness of a 6-week physical exercise program on cognitive domains and hand grip strength between the intervention and control groups of undergraduate students in the Faculty of Allied Health Sciences

Methods

The study was structured as a randomized controlled trial conducted within the confines of the Faculty of Allied Health Sciences. Participants included undergraduates enrolled in the second year of the first semester using the stratified random sampling method. Participants were divided into five strata based on their representative departments (Nursing, Medical Laboratory Sciences, Pharmacy, Physiotherapy, and

Radiotherapy/Radiography), and each stratum was proportionally represented in the sample. Within each stratum, chits labelled “Study group” and excluded group”were put into a box and participants were instructed to randomly pick a chit. The number of chits matched the proportion of participants in each department and sex. Strict inclusion criteria were applied, limiting participation to undergraduates within the specified age bracket of 20–30 years who met the prerequisites for a 6-minute walk test. In addition, research studies encompassed first-semester, second-year undergraduates, specifically before the commencement of their clinical training. Conversely, individuals with health conditions prohibiting moderate-to-high PA, those engaged in university or other sports teams, and undergraduates regularly involved in PE were excluded.

The sample size was calculated using the Gpower software version 3.1.9.4. The formula used is as follows:

Effect size = medium effect, 0.35

α err pob = 0.05

Power (1-β err prob) = 0.8

Number of groups = 2

Number of measurements = 2

The output indicated:

Noncentrality parameter λ = 13.5000000

Critical F = 4.0266314

Numerator df = 1.0000000

Denominator df = 52.0000000

Total sample size = 67

Considering a dropout rate of 10%, the total sample size for both groups is projected to be 74. Therefore, the sample size allocated to each group was 37 using a stratified random sampling method. Stratification was based on five academic departments (Nursing, Medical Laboratory Sciences, Pharmacy, Physiotherapy, and Radiotherapy/Radiography) and a proportional sample was obtained from each department. Chits labelled “Study group” and “Excluded group” were placed in a box and participants were asked to pick one randomly. Figure 1 shows the Consolidated Standards of Reporting Trails (CONSORT) flowchart for participant recruitment.

The data collection tools encompassed comprehensive sheets that gathered demographic information, anthropometry, disabilities, and details regarding illnesses that might impede PA. These sheets were instrumental in assessing cognitive abilities using the Montreal Cognitive Assessment alongside hand grip measurements.

The data collection method involved ethical clearance procedures, departmental permissions, and a thorough briefing of undergraduate students about the objectives of the study. Utilizing random allocation to the intervention or control groups, the research team conducted pre- and post-exercise assessments of cognitive ability and hand grip strength.

The subjects were randomly assigned to either the exercise or control group using random numbers generated using SPSS. Each participant, regardless of the group, underwent HGS assessments and completed the Montreal Cognitive Assessment at the outset. Subsequently, the exercise group commenced a 6-week exercise program, whereas the control group continued regular physical activities without any imposed limitations.

The exercise sessions were scheduled from 6:00 p.m. to 7:00 p.m., a timeframe considered suitable for undergraduate students to engage in after their academic commitments. Before initiating the exercise program, the participants were provided with a Zoom link for instructions and encouraged to join the session. The principal investigator led the exercises, while the other investigators observed the exercises remotely via video calls or zoom meetings. Contingency plans were in place for participants who were unable to participate at the designated time, with alternate feasible times. The principal investigator provided assistance through zoom or video calls.

Throughout the study, emphasis was placed on participants’ rights to refuse or withdraw from the program, ensuring that their decisions did not impact their academic pursuits. Safety measures were paramount, with participants being educated about potential danger signs during exercise (such as dizziness, discomfort, headache, palpitation, or breathlessness). Additionally, the participants were monitored during the initial onsite training, and instructions were provided regarding when to cease the exercises if they experienced difficulties.

At the culmination of the 6-week period, both the intervention and control groups were requested to repeat the Montreal Cognitive Assessment and perform handgrip strength measurements. The MoCA requires approximately 10 min to complete. By comparing 30 items, this assessment evaluated diverse cognitive domains: short-term memory (five points), visuospatial skills (four points), executive functioning involving an adapted Trail Making Test Part B (one point), phonemic fluency (one point), and verbal abstraction (two points). It also assessed attention, concentration, and working memory through target detection (1 point), serial subtraction (3 points), forward digits (1 point), and backward digits (1 point). Language skills were gauged by confrontation naming with low-familiarity animals (three points) and repetition of complex sentences (two points). Additionally, orientation to time and place (six points) formed a significant part of the assessment [19]. Hand grip strength, which is considered a predictive measure of overall muscle strength, was evaluated using a hand dynamometer. Three measurements were taken per hand, allowing a 30-second rest period between each measurement, and this process was conducted for both hands in line with established protocols [27].

The exercise group in this study underwent a structured program centered on moderate-to-vigorous-intensity strengthening exercises. Cognitive ability and hand grip strength were assessed before and after the exercise program to measure any potential improvements. The initial day included physical demonstrations by the researchers to showcase the correct execution of exercises and prevent injuries. The team received thorough training to conduct the study efficiently and to correct deviations from the prescribed procedures.

The participants were provided with in-person demonstrations and a subsequent video illustrating the exercises to ensure proper comprehension and adherence. They were then asked to perform these exercises in their boarding places or hostels with reminders for each session, and were provided a log to track their participation. The exercise frequency was set at three days per week, with each session lasting 36 minutes, a duration backed by previous literature for positive cognitive impact [1,24]. Additionally, a one-day interval between exercise sessions was advised for optimal results. Hydration guidelines emphasizing drinking water before, during, and after exercise were communicated to prevent dehydration.

The exercise routine itself encompasses a warm-up comprising various activities such as jogging on the spot, butt kicks, leg swings, and arm rotations. The core exercise routine involved a series of movements such as arm swings, squats, plank variations, jumping jacks, and high knees, interspersed with specific rest periods. The session concluded with a cool down that included activities such as standing stretches, overhead arm stretches, upper body twists, and gradual relaxation techniques, summing up to a comprehensive 36-minute session. On the other hand, the control group was instructed to continue their usual activities without any alterations or limitations imposed by the study.

Ethical considerations were paramount, and clearance was obtained from the Ethics Review Committee to ensure data confidentiality and participant anonymity throughout the study. The analysis involved a comprehensive statistical examination using the SPSS software (version 22). Demographic information is presented using descriptive statistics. The Shapiro-Wilk test was used to determine the normality distribution of the data. Pre- and post-exercise comparisons within groups for cognitive domains and handgrip strength were conducted using a paired t-test. A comparison between the intervention and control groups for cognitive domains and handgrip strength was performed using an independent-sample t-test.

Results

There were 74 participants from five degree programs in the Faculty of Allied Health Sciences. The details of the study participants are presented in Table 1.

The demographic data in Table 1 encompassed 74 participants that were evenly distributed between the control and exercise groups. Both groups showed similar characteristics in terms of age, with a mean age of 23 years and standard deviation (SD) of 1. The sex distribution was balanced within the groups, maintaining an equal representation of males and females. Departments among the participants were evenly distributed across Medical Laboratory Science (MLS), Radiography, Nursing, Pharmacy, and Physiotherapy in both the control and exercise groups.

The results in Table 2 reveals that the mean HGS on the dominant hand significantly increased from 26.58 kg $\pm$12.84 pre-exercise to 30.38 kg $\pm$13.16 post-exercise ($t = -7.350$, $p < 0.05$). Similarly, in the non-dominant hand, there was a notable rise in mean HGS from 24.57 kg ±11.76 to 27.6332 kg ±11.58 post-exercise ($t = -8.973$, $p < 0.05$).

Regarding cognitive assessment using the MoCA, the exercise program showed significant improvements in total MoCA scores, increasing from a mean of 24.76±2.12 pre-exercise to 28.57±1.191 post-exercise ($t = -14.687$, $p < 0.05$). Within specific cognitive domains, executive function and visuospatial function increased from a mean of 4.68± .53 to 5.00±.00 ($t = -3.723$, $p = .001$), while naming abilities rose from 2.70± .52 to 3.00±.00 ($t = -3.479$, $p = .001$).

Moreover, improvements were observed in language skills, with mean scores increasing from 1.70±SD = .52 to 2.38 ±SD = .54 ($t = -6.565$, $p < 0.05$), and delayed recall abilities showed significant enhancement from 2.70±1.15 to 4.49±SD = .69 ($t = -11.833$, $p < 0.05$). Orientation skills also improved, rising from a mean of 4.97±1.14 to 5.86±.53) ($t = -5.049$, $p < 0.05$). However, attention and abstraction did not significantly change after exercise.

Overall, the exercise intervention exhibited noteworthy enhancements in handgrip strength and various cognitive domains, signifying the positive impact of the exercise program on both the physical and cognitive aspects within the exercise group (Table 2).

The results in Table 3 show that marginal changes were observed in both the dominant and nondominant hands. For the dominant hand, mean HGS displayed minimal variation from 25.45 kg ±11.49 pre-exercise to 25.01 kg ±11.31 post-exercise ($t = 0.7185$, $p = 0.474$). Similarly, the non-dominant hand exhibited slight changes from 23.71 kg±10.83 pre-exercise to 23.06 kg ±10.31 post-exercise ($t = .724$, $p = .291$).

When assessing cognitive functions using the MoCA, the control group showed a noteworthy increase in the total MoCA score, rising from a mean of 25.08 ±1.97 pre-exercise to 25.57 ±2.03 post-exercise, though this change was only marginally significant ($t = 1.071$, $p = .037$).

Within specific cognitive domains, there were limited changes after exercise. Executive function, visuospatial function, naming ability, attention, language, and abstraction did not exhibit significant alterations. However, delayed recall showed a slight increase from a mean of 2.38±SD = 1.03 to 2.62 ±1.16 post-exercise, indicating a modest improvement ($t = -2.165$, $p = .037$). Orientation skills remained relatively stable, with minimal changes.

Overall, the control group demonstrated minor variations in handgrip strength and limited changes in cognitive function post-exercise. While there were slight improvements in certain cognitive domains, particularly in delayed recall, the overall impact was less pronounced than in the exercise group.

Table 4 reveals that the exercise group demonstrated significantly higher post-test mean values in both the dominant hand (30.38 kg±13.16) and the non-dominant hand (27.63 kg±11.58) compared to the control group (dominant hand: 25.01 kg±11.31; non-dominant hand: 23.06 kg, ±10.31). In addition, the variability statistics indicated that, while the control group showed the same variability (45%) for both pre- and post-test values, the exercise group showed a 3% reduction in variability after the exercise program. This suggests that the exercise program helped stabilize participants' performance. However, while the differences were notable, they did not reach statistical significance for the dominant hand ($t = -1.884$, $p = .064$) or the non-dominant hand ($t = -1.791$, $p = .078$) at the 5% level. at a 95% Confidence Interval.

In terms of cognitive assessments using the MoCA, the exercise group exhibited significantly higher post-test mean scores (28.57±1.19) than the control group (25.57±2.03), indicating substantial improvement in cognitive functioning post-exercise ($t = -7.739$, $p < 0.05$). In addition, the exercise group demonstrated a 4% variability reduction (8% to 4%), whereas the control group exhibited no such stability.

When examining specific cognitive domains, the exercise group displayed statistically significant improvements in various areas compared with the control group. These included language ability ($t = -4.195$, $p < 0.05$), delayed recall ($t = -8.381$, $p < 0.05$), and orientation ($t = -3.786$, $p < 0.05$). Notably, executive function, visuospatial function, naming, attention, and abstraction did not differ significantly between the exercise and control groups.

Overall, the exercise group showed notable enhancements in hand grip strength and various cognitive domains compared to the control group, emphasizing the positive impact of the exercise program on both physical and cognitive aspects among participants.

Discussion

In our study, we observed significant improvements in both HGS and cognitive function among participants who underwent a 6-week strengthening exercise program. These findings are particularly significant for second-year first-semester allied health science students, including those in MLS, pharmacy, physiotherapy, nursing, and radiography programs. The strengthening exercises we implemented were effective in increasing HGS in both the dominant and non-dominant hands, which is essential for manual dexterity and professional competence required in allied health science fields.

MoCA revealed substantial improvements in executive function, visuospatial function, naming ability, language skills, delayed recall, and orientation in the exercise group. These cognitive domains have profound relevance for allied health science students, signifying the exercise program's potential to enhance cognitive abilities crucial for their academic endeavors and future career prospects [6,17].

Physiologically, our results are consistent with prior research indicating that strengthening exercises induce neurobiological adaptations in the central nervous system [28]. These adaptations include increased levels of neurotrophic factors such as BDNF, improved cerebral blood flow, and heightened synaptic plasticity. These mechanisms likely contributed to the observed enhancements in both physical strength and cognitive function among participating students [28]. In addition, the exercise program reduced both handgrip strength (4%) and cognitive function (4%), suggesting its role in enhancing stability in both physical and cognitive outcomes.

Despite non-significant changes in attention and abstraction post-exercise, further investigation is warranted to understand the specific exercise parameters required to effectively influence these cognitive domains among allied health-science students. Comparatively, the control group displayed marginal alterations in HGS and limited changes in cognitive function post-exercise. Although slight improvements were evident in certain cognitive domains, particularly delayed recall, the overall impact was less pronounced than that in the exercise group.

The exercise group demonstrated significantly higher mean HGS values for both the dominant and non-dominant hands than the control group, emphasizing the substantial impact of the exercise program. Moreover, the exercise group exhibited significant improvements in various cognitive domains, including language ability, delayed recall, and orientation, underscoring the profound influence of PA, especially targeted strengthening exercises, on both physical and cognitive facets among university students pursuing related health sciences.

This result aligns with previous research suggesting that maintaining a higher level of PA is linked to a reduced risk of cognitive impairment among individuals [29,30]. Regarding studies focusing directly on undergraduates and the effects of strength training on cognitive function and hand grip strength, the research is indeed limited. Most existing studies exploring these associations tend to concentrate on older adults. Chang in 2017 investigated the relationship between hand grip strength (HGS) and cognitive function [29]. They discovered that a higher baseline HGS correlated positively with better cognitive performance, measured using the Mini-Mental State Examination (MMSE), both before and after a 12-week resistance exercise program [29]. This study suggests that individuals with greater HGS may exhibit improved cognitive abilities, highlighting a potential link between physical strength and cognitive function among young adults [29].

Additionally, while Wang et al. (2023) emphasized the importance of maintaining higher levels of PA in reducing the risk of cognitive impairment [30], a strengthening exercise program demonstrated similar increases in cardiorespiratory fitness and muscular strength (Δ total hand grip $\geq$ 3%) compared with the control group. This 12-week structured exercise intervention notably enhanced physical fitness among sedentary middle-aged adults irrespective of the specific training regimen [8]. This broader study implies that engaging in regular PA could positively impact cognitive health and HGS, potentially extending to the undergraduate population.

Incorporating structured exercise programs into the academic curriculum is pivotal for enhancing physical activity among university students. Strategies such as providing access to fitness facilities, educating students on the importance of regular PA, and integrating physical activity breaks into academic schedules could effectively augment students' engagement in PE.

Moreover, the findings accentuate the positive influence of a targeted strengthening exercise program on physical strength and cognitive function among university students in the allied health sciences. Integrating PA initiatives within the academic curriculum is crucial for fostering holistic student development, preparing students for future roles in the healthcare sector, and improving their overall wellbeing.

The present study explored the effectiveness of a 6-week exercise program among a batch of undergraduates from five degree programs; hence, the results may not be generalizable. However, the study investigated the effects of an exercise program that was developed considering principles for a strengthening exercise program on HGS and cognitive functions among early year undergraduates of Health Sciences degrees. The results have shown that the exercise program was effective in improving HGS and cognitive functions among early year health sciences undergraduates before initiating clinical training, this exercise program can be investigated further among different years of study among undergraduates and the efficacy be determined. The exercise program should also be evaluated for a larger sample and non-health science undergraduates.

Conclusion and Recommendation

The present study concluded that the exercise group exhibited substantial improvements in both dominant and non-dominant HGS, accompanied by marked enhancements in cognitive functions, notably executive function, naming abilities, language skills, delayed recall, and orientation, compared with the control group. In contrast, the control group displayed minor variations in HGS and limited changes in cognitive function post-exercise, with only slight improvements in delayed recall, indicating a less pronounced impact than the exercise group. Notably, statistical analyses comparing the exercise and control groups revealed significant differences in the HGS and several cognitive domains, emphasizing the role of the exercise program in augmenting both physical and cognitive parameters. These findings underscore the improvements in cognitive domains after the structured strengthening exercise program, suggesting its potential value in supporting cognitive health. Therefore, integrating structured exercise programs into academic curricula and promoting regular PA among university students could enhance both physical and cognitive health.

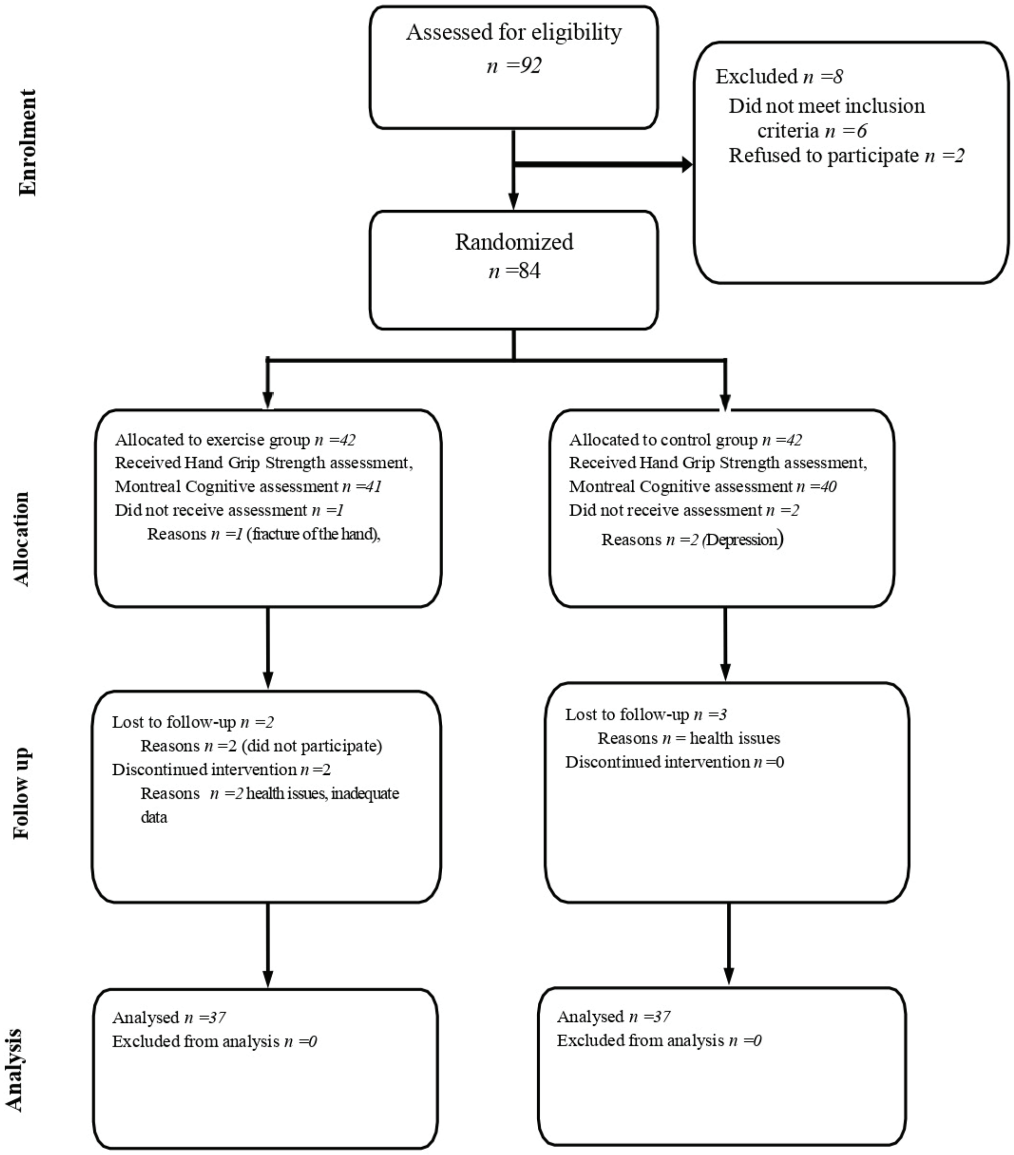

Figure 1: CONSORT (Consolidated Standards of Reporting Trials) flow chart of participant recruitment

Table 1: Demographic information (n=74)

Characteristics		Group	n	Mean± SD
Age		Control	37	23±1
		Exercise	37	23±1
Gender	Male	Control	11	
	Female	Exercise	26	
	Male	Control	11	
	Female	Exercise	26	
Department	Medical Laboratory Sciences	Control	5	
		Exercise	5	
	Radiography	Control	11	
		Exercise	11	
	Nursing	Control	8	

		Exercise	8	
	Pharmacy	Control	5	
		Exercise	5	
	Physiotherapy	Control	8	
		Exercise	8	
Physical Activity Level	Inactive	Control	25	
		Exercise	21	
	Minimally active	Control	8	
		Exercise	11	
	HEPA	Control	4	
		Exercise	5	
Height		Control	37	1.60±0.07
		Exercise	37	1.59±0.08
Weight		Control	37	54.52±10.52
		Exercise	37	52.76±9.08
BMI		Control	37	21.33±3.55
		Exercise	37	21.04±3.48

Table 2: The pre and post exercise assessment of cognitive domains and hand grip strength in the exercise group (n=37)

Variables	Pre-Exercise (Mean ± SD)	Post-Exercise (Mean ± SD)	t	Sig. (2-tailed)
HGS in dominant hand (kg)	26.58±12.84	30.38±13.16	-7.350	0.000*
HGS in non-dominant hand	24.57±11.76	27.63±11.58	-8.973	0.000*
Total MoCA Score	24.76±2.12	28.57±1.19	-14.687	0.000*
Executive function and visuospatial function	4.68±.53	5.00±.00	-3.723	0.001*
Naming	2.70±.52	3.00±.00	-3.479	0.001*
Attention	5.86±.58	5.95±.22	-1.357	0.183
Language	1.70±.52	2.38±.54	-6.565	0.000*
Abstraction	1.97±.16	2.00±.00	-1.000	0.324
Delayed recall	2.70±1.15	4.49±.69	-11.833	0.000*
orientation	4.97±1.14	5.86±.53	-5.049	0.000*

Table 3: The pre and post exercise assessment of cognitive domains and hand grip strength in the control group (n=37)

Variables	Pre-Exercise Mean ± SD)	Post-Exercise (Mean ± SD)	t	Sig. (2-tailed)
HGS in dominant hand (kg)	25.45±11.49	25.01±11.31	−0.7185	0.474
HGS in Non-dominant hand	23.71±10.83	23.06±10.31	0.724	0.291
Total MoCA Score	25.08±1.97	25.57±2.03	1.071	0.037*
Executive function and visuospatial funtion	4.97±.16	5.00±.00	-2.165	0.324
Naming	2.95±.22	3.00±.00	-1.000	0.160
Attention	5.97±.16	5.97±.16	-1.434	0.183
Language	1.70±.46	1.81±.61	-1.160	0.254
Abstraction	1.92±.27	1.97±.16	-1.434	.160
Delayed recall	2.38±1.03	2.62±1.16	-2.165	.037*
orientation	5.03±1.19	5.08±1.14	-.627	.534

Table 4: Comparison between the exercise and control group (n=74)

Variable	Group of the participant	Mean± SD	t	Sig. (2-tailed)
HGS in dominant hand	control group	25.01±11.31	-1.884	0.064
	Exercise group	30.38±13.16		
HGS in Non-dominant hand	control group	23.06±10.31	-1.791	0.078
	Exercise group	27.63±11.58		
MoCA Score	control group	25.57±2.03	-7.739	0.000*
	Exercise group	28.57±1.19		
Executive function and visuospatial function	control group	5.00±.00[a]		
	Exercise group	5.00±.00[a]		
Naming	control group	3.00±.00[a]		
	Exercise group	3.00±.00[a]		
Attention	control group	5.97±.16	.583	0.562
	Exercise group	5.95±.22		
Language	control group	1.81±.61	-4.195	0.000*
	Exercise group	2.38±.54		
Abstraction	control group	1.97±.16	-1.000	0.324
	Exercise group	2.00±.00		
Delayed recall	control group	2.62±1.16	-8.381	0.000*
	Exercise group	4.49±.69		
orientation	control group	5.08±1.14	-3.786	0 .000*
	Exercise group	5.86±.53		

HGS, Hand Grip Strength; MoCA, Montreal Cognitive Assessment; * $p<0.05$ Correlation is significant at the 0.05 level (2-tailed): t cannot be computed because the standard deviations of both groups are 0

Author declaration

Author contributions: All authors contributed to the conceptualization and design of the study. Wijayasinghe W.A.D.H.M, and Liyanage E. contributed to the acquisition of data. Wijayasinghe W.A.D.H.M. conducted the data analysis. Wijayasinghe W.A.D.H.M, and Liyanage E. contributed to data interpretation and writing the manuscript. All the authors have read and approved the final manuscript.

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