Article

Effects of Physical Activity on Physical Fitness and Functional Ability in Older Adults

Gerontology & Geriatric Medicine
Volume 9: 1–10
© The Author(s) 2023
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/23337214231158476
journals.sagepub.com/home/ggm
SAGE

Bimba Wickramarachchi, PhD[1,2], Mohammad R. Torabi, PhD[3], and Bilesha Perera, PhD[1]

Abstract

A cross-sectional survey was done to investigate the pathways the physical activity acts in improving physical fitness and functional outcomes of older adults (60 years and above) using 880 community-dwelling older adults in Sri Lanka. Structural Equation Modeling (SEM) was used. The final SEM model included five latent factors and 14 co-variances. Goodness of Fit Index (GFI), Comparative fit index (CFI) and Root Mean Square Error of Approximation (RMSEA) values of the model were 0.95, 0.93, 0.91, and 0.05 respectively, indicating a good model fit. Strength enhances balance ($\beta = .52$, $p < .01$) and reduces the time required to complete physical functions ($\beta = -.65$, $p < .01$). Since strength declines with advancing age, muscle-strengthening activity programs should be promoted to enhance balance and functional performances in older adults in advanced ages. Strength test (hand grip and leg strength) can be used as a screening test to predict potential risk of falls and functional disabilities in older adults.

Keywords

physical fitness, physical functions, older adults, physical activity, Sri Lanka

Manuscript received: October 11, 2022; **final revision received:** January 22, 2023; **accepted:** February 2, 2023.

What this paper adds

- Illustrate how physical activity behavior influence physical fitness and functional ability in older adults
- Muscle-strength is the single most important contributor for balance and physical functions of older adults

Application of study designs

- Older adult health promotion programs should pay attention to incorporate muscle- strength promotion activities in such programs, and encourage young older-adults to practice muscle-strength physical activities.
- Hand grip and leg strength tests can be used as screening tests to predict potential risk of falls and development of functional disabilities in older adults.

Introduction

Population aging is a worldwide phenomenon; the global share of older adults (aged 60 years or over) increased from 9.2% in 1990 to 11.7% in 2013 and will continue to grow, reaching to 21.1% by 2050 (United Nations, 2022). Physical activity is considered as a key to successful and healthy aging (Hallal et al., 2012; World Health Organization, 2022) because regular physical activity plays a significant role in enhancing physical fitness, functional ability and quality of life in old age (Blewitt & Chockalingam, 2017; Stavrinou et al., 2022; Tyndall et al., 2018). Age-related physical decline and corresponding loss of functional capacity are related to the loss of muscle mass (sarcopenia), decrease of aerobic capacity and joint range motion, changes in the sensory system, and consequently would reduce mobility and fitness (Elam et al., 2021; Nelson et al., 2007). It has been shown that physical inactivity reduces the muscle mass and joint motion by about 10% to 40% in older adults (Tieland et al., 2018). Losses in muscular strength occur at an approximate rate of 12% to 14% per decade after the age of 50 years, and balance disorders increase with aging resulting in accidental falls among older

[1]University of Ruhuna, Galle, Sri Lanka
[2]Universiti Malaysia Sarawak, Kota Samarahan, Malaysia
[3]Indiana University, Bloomington, IN, USA

Corresponding Author:
Bilesha Perera, Department of Community Medicine, Faculty of Medicine, University of Ruhuna, P.O.Box 70, Galle 80000, Sri Lanka.
Email: bileshap@med.ruh.ac.lk

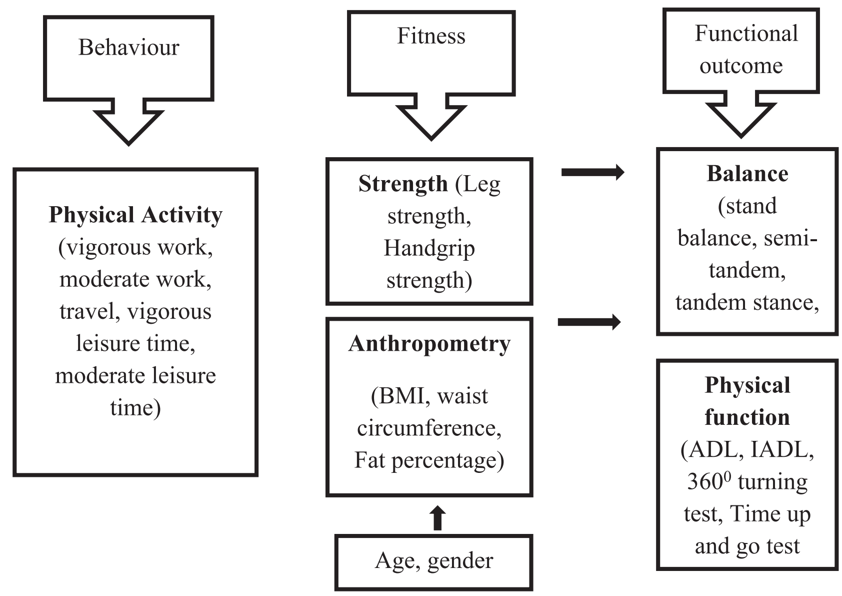

Figure 1. Hypothetical model on the relationship between physical activity behavior, fitness and functional outcome (adapted from Blair et al., 2001).

adults (Volaklis et al., 2015). It was found that there is a gradual increase of fall by 35% to 40% after the age of 60 years (World Health Organization, 2007). Physical activity enhances balance and strength of the older adults resulting in the prevention of falls and improving physical function and quality of life of the older adults (Ferreira et al., 2012; Stavrinou et al., 2022; Wannamethee & Atkins, 2019; World Health Organization, 2007). Studies on improving balance, strength and endurance (Bootsman et al., 2018; Ferreira et al., 2012; Zouita et al., 2020), relieving pain and enhancing functional mobility (Tse et al., 2011, 2013), and preventing frailty (Mesquita et al., 2015; Trombetti et al., 2016) in old age have shown that physical activity is positively associated with functional health. Balance control is found to be the main ability which is needed to maintain physical function and independence in old age.

The population in Sri Lanka is growing older very fast compared to most of the other developing economies (Asian Development Bank, 2019). Resource limitations in the country have already hampered geriatric health care services, making it difficult to initiate large scale population based interventions to support older adults who are suffering from physical impairments. Therefore, culture sensitive, community based and low cost strategies are needed to support older adults to maintain their day today activities and daily functions at a satisfactory level. Physical fitness of older adults is a key area where low-cost community interventions can be developed to maintain psychological and physical well-being of Sri Lankan older adults. Scientific evidences related to physical fitness and functional abilities of older adults in the country are scarce. The purpose of this research was to examine relationships between physical activity, fitness and functional abilities of community-dwelling older adults in Sri Lanka. Blair et al. (2001) in their study on relationships between behavior, fitness and health outcomes, considered physical activity as a modifiable behavioral factor on changing fitness and health outcome. Our study adapted his model (Figure 1) and tested that model using structural equation modeling (SEM) technique. This model has not been tested using an Asian older population, and therefore our study would greatly help gerontologists and other health care professionals in Asian countries to understand interrelationship of physical activity, physical fitness and functional abilities in older adults using Blair's model, and to develop strategies based on the results to promote health of this target population.

Methods

Setting and Research Design

The study was conducted in a Western district in Sri Lanka. The country, a lower middle-income country in south Asia, is at present facing an unprecedented economic crisis. Sri Lanka's population is rapidly aging but adequate attention has not been paid by government and health authorities to strengthen gerontological and geriatric care services in the country. This cross-sectional survey of older adults was conducted in January to March, 2018.

Sampling

A sample of 880 older adults (aged 60 years and older) was surveyed. Multistage cluster sampling method was employed to select the participants. Two Divisional

Secretariat (DS) areas out of 13 in the Colombo district in Western province in Sri Lanka were selected first. Ten Grama Niladari (GN) areas from each of the two selected DS division were then selected. Forty-four community clusters were randomly identified from the selected GN areas as the data collections units. Older adults who were severely sick, poor cognitive state (Mini-Mental State Exam <17) and those who were with communication difficulties were excluded. Older adults who have migrated or moved to another district during the data collection period, homeless older adults and older adults who were unable to speak Sinhala were also excluded from the study. Researcher administered questionnaire was used and physical assessments were conducted by the researcher and a trained research assistant. Investigations and filling the questionnaires were conducted in the older adults' home.

Data Collection Instruments and Procedure

Physical Activity. Physical activity was assessed by using GPAQv2. This is a 16 item questionnaire, which provides domain-specific physical activity including work, travel and leisure-time related activities by mean Metabolic Equivalence Task per week (MET/week). This tool was validated for the community-dwelling older people in Sri Lanka (Wickramarachchi et al., 2021).

Anthropometrical Measures. Height: Standing height without shoes was measured to the nearest 0.5 cm.

Weight: Body weight was measured to the nearest 0.1 kg by a beam balance with light clothes, without shoes.

Body Mass Index: BMI was calculated using height and weight (kg/m^2).

Waist circumference: Waist circumference was taken by a non-elastic tape to the nearest 0.1 mm.

Fat percentage: Fat percentage was tested based on the skinfold thickness using the Harpenden skinfold caliper (precision 0:2 mm, Harpenden skinfold caliper, John Bull British Indictor Ltd, UK). Recordings of four sites; biceps, triceps, supra-iliac and sub scapula were taken using the left side of the body. It was measured to the nearest 0.1 mm. Two measurements at each site were taken and the average was calculated. Durning and Womersley (1974) method was used to get the fat percentage.

Strength. Hand grip strength: Handgrip strength was measured using a dynamometer (TANITA, no 6103, Japan). The participant was instructed to stand, and two recordings were taken using the dominant hand. If the difference was more than 3 kg, the test was repeated once, and the average was taken.

Leg strength: The "30 second chair stand test" was done to assess the lower extremity muscle power. The participant was asked to stand up and sit down on a chair repetitively for 30 s. The score was calculated based on the total number of completed chair stands in 30 s. Three measures were taken, and the average was calculated.

Functional Status. 360° turning test: the person was instructed to turn himself/herself 360° and the time taken to turn was recorded. Two measures were taken, and the average was calculated.

Stand up and go test: the person was asked to stand up and walk 3 m and turn back to the chair and sit down. Time taken for the activity was taken. This test was performed two times and the average was calculated and recorded.

Independence in Activities of Daily Living (Katz ADL): The participant's ability to perform activities of daily living independently was measured using six items; bathing, dressing, toileting, transferring, continence, and feeding. Three-point response scale that assessed independence, some assistance, or dependent status of the person was used. This tool has been used in a number of gerontological research studies in Sri Lanka

Instrumental Activities of Daily Living (IADL): Independent living skills of the participants were assessed. This tool comprises eight items, including the ability to use the telephone, shopping, food preparation, housekeeping, doing laundry, mode of transportation, responsibility of own medication and ability to handle finances. The score of the tool ranges from 0 to 8 and higher scores indicates higher levels of independent living skills. The tool has been validated for the older adults in Sri Lanka (Siriwardhana et al., 2018).

Balance. Four stage balance test was performed including balanced stand, semi-tandem, tandem stance and stand on one leg. Each task was tested for 10 s. Each participant was asked to do each activity twice and the average of the two measures were taken. Total score of the test is 40. Higher score indicates a good static balance. Not being able to hold the tandem stance for 10 s is an indication of increased risk of fall.

Data Analysis

Means and SDs of the quantitative variables were calculated. Structural equation modeling (SEM) was used to examine the interrelationships between GPAQv2 score with balance (four-stage balance), strength (hand grip strength, leg strength) and anthropometrical measures (BMI, fat percentage, waist circumference). Data coding, entering and treating for the outliers were done appropriately. SPSS data analysis package (version, 25) was used to perform descriptive and correlation analysis. Agreement of coefficients were interpreted as 0 to .2 = poor, .21 to .40 = fair, .41 to .60 = moderate/acceptable, .61 to .80 = substantial and .81 to 1.0 = near perfect (Landis & Koch, 1977). The 95% confidence interval (CI) was calculated as the mean difference ± 1.96 x standard error.

SEM was done using AMOS Graphics (25 version) software program using the maximum likelihood estimator with robust standard errors. Bollen–Stine bootstrapping with 10,000 drawn samples was used to calculate Bollen–Stine *p*-value to assess the overall model fit. In

Table 1. Socio-Demographic Characteristics of Participants ($n = 880$).

Variable		N (%)
Age	60–69	437 (49.7)
	70–79	387 (44)
	80–89	51 (5.8)
	90 and above	5 (0.6)
Gender	Male	220 (25)
	Female	660 (75)
Education	No formal education	20 (2.3)
	Below grade 5	96 (10.9)
	Grade 5 to O/L	426 (48.4)
	Up to A/L	249 (28.3)
	Diploma/ certificate	46 (5.2)
	Graduate	28 (3.2)
	Post Graduate	15 (1.7)
Income (Rs)	Below 5,000	300 (34.1)
	5,000–10,000	17 (1.9)
	10,000–30,000	240 (27.3)
	30,000–100,000	196 (22.3)
	Over 100,000	127 (14.4)
Living Arrangements	Alone	106 (12)
	Living with spouse	481 (54.7)
	Living with spouse and children	109 (12.4)
	Living with children	170 (19.3)
	Other	14 (1.6)

this study, first we evaluated measurement model with a number of factors followed by a structural model to confirm the direct and indirect effects. Absolute and relative fit of the model was tested. Absolute fit indices of chi-square (χ^2) <0.05; RMSEA < 0.1; GFI > 0.9 were taken as good fits. NFI, IFI, CFI, AGFI, and TLI >0.9 (the range is 0 to 1) was taken as good (Bentler & Bonett, 1980).

Analysis of Global Physical Activity Questionnaire (Version 2). Global Physical Activity Questionnaire analysis guide was used (World Health Organization, 2021). Outcome MET value was computed by multiplying the MET score of activity by the total number of minutes performed. When calculating a person's overall energy expenditure, four Four METs get assigned to the time spent in moderate activities and travelling, and eight METs to the time spent in vigorous activities. If any participant has done >16 hrs of physical activity for any subdomain those cases were removed according to the analysis guide. If a person gives a value for only one domain and others are missing then the missing domains get "0" value.

Ethics

Participants who volunteered to participate in the study were recruited for the study and their written informed consents were obtained. Ethical approval was obtained from the Ethics Committee of the Faculty of Allied Health Sciences, University of Ruhuna, Galle, Sri Lanka (12.07.2018: 3.1).

Results

Among the total of 898 respondents, 16 were incomplete questionnaires and 2 outliers were removed. Thus, a total of 880 sample subjects was retained for the final analysis.

Descriptive and Demographic Characteristics

Socio-demographics variables including age, gender, education, income and living status are presented in Table 1. The majority were female (75%) and only 0.6% of the participants were 90 years or above. Means and standard deviation of the 18 observed variables that come under five constructs were tested based on gender and age (Table 2).

The final model is shown in Figure 2. A multivariate normality test was performed, and outliers were checked by inspecting the Mahalanobis distance. As multivariate outlier exists, bootstrapping was performed. Bollen–Stine *p*-value was taken as .001.

Hypothesized direct and indirect effects were added to the measurement model. The correlated first order latent-factor measurement model did not provide an adequate fit to the data. Statistically significant standardized regression weights were identified if their p value is $< .05$, and the overall model was changed accordingly. Constructs on vigorous leisure-time physical activity, moderate leisure-time physical activity, ADL and IADL were removed from the structural model as their relationships were not significant. The modification indices suggested for inclusion of alternative correlations for better fitting of the model. Direct influences of physical activity and age on strength and anthropometric measures and indirect influences of anthropometric measures and strength on balance and functions were observed.

Second order confirmatory structural model (final model) (Figure 2) included five latent factors and 14 covariances. This model gave chi-square (χ^2) goodness of fit test p values greater than .05, which confirmed the global fit of the confirmatory model. GFI, AGFI, CFI, TLI, NFI, IFI, and RMSEA values were 0.95, 0.93, 0.93, 0.91, 0.92, 0.93, and 0.05, respectively, which indicated a good model fit (Bentler & Bonett, 1980).

The final model significantly predicted the observed variables ($p < .05$). The variances of balance, strength, anthropometric measures, functional status and error terms were all significant ($p < .05$). Estimated standardized regression weight to the tested directions are given in Table 3. The loadings indicate all the effects to the expected directions except for the impact of

Table 2. Mean (Standard Deviation) Values of the Measured Parameters ($n = 880$).

Variable	Total N=880	Male N=220	Female N=660	p	Age 60–69 N=437	70–79 N=397	80–89 N=51	>90 N=5	p
Physical activity									
Total PA	3,299 (3,169)	2,862 (3,150)	3,444 (3,165)	.01	3,873 (3,426)	2,917 (2,877)	1,467 (1,507)	133 (1,832)	.00
Vigorous work	247 (1,288)	322 (1,211)	221 (1,211)	.07	316 (1,545)	204 (1,034)	0	0	.28
Moderate work	2,317 (2,537)	1,499 (2,332)	2,590 (2,546)	.07	2,823 (2,795)	1979 (2,210)	765 (1,126)	48 (65)	.00
Travel	468 (895)	494 (1,044)	460 (841)	.17	491 (834)	448 (971)	419 (824)	616 (849)	.85
Vigorous leisure time	–	–	–	–	–	–	–	–	–
Moderate leisure time	265 (664)	545 (950)	172 (503)	.00	241 (653)	285 (692)	283 (499)	672 (920)	.41
Anthropometry									
BMI	25.8 (5.7)	24.0 (3.5)	26.5 (6.1)	.00	26.8 (5.0)	25.4 (6.3)	21.4 (3.0)	20.2 (3.0)	.00
Waist circumference	90.8 (13.8)	89.6 (13.1)	91.2 (14.0)	.28	92.9 (12.9)	89.6 (14.0)	84.2 (9.6)	64.7 (35.6)	.00
Fat percentage	37.2 (7.6)	27.1 (5.6)	40.6 (4.6)	.00	39.3 (6.6)	35.9 (7.7)	30.0 (8.1)	26.9 (3.6)	.00
Strength									
Handgrip	17.2 (0.0)	21.8 (5.3)	15.6 (6.2)	.03	17.5 (4.9)	17.16 (8.1)	15.6 (5.9)	12.8 (2.5)	.11
Leg strength	9.9 (6.5)	9.9 (3.5)	9.8 (3.1)	.13	10.3 (2.8)	9.5 (3.3)	8.3 (4.3)	7.6 (1.1)	.00
Physical function									
360° turning test	2.7 (1.7)	2.6 (1.6)	2.8 (1.7)	.23	2.5 (1.5)	2.8 (1.7)	3.6 (1.5)	7.3 (6.5)	.00
Time up and go test	10.0 (4.6)	9.7 (6.6)	10.1 (3.8)	.07	9.0 (2.8)	10.7 (6.0)	12.7 (3.4)	17.2 (3.0)	.00
ADL	11.7 (1.1)	11.6 (1.3)	11.7 (1.0)	.00	11.5 (1.3)	11.8 (0.8)	11.8 (0.9)	12 (0.0)	.02
IADL	7.5 (1.3)	7.5 (1.2)	7.5 (1.3)	.38	7.4 (1.3)	7.5 (1.4)	7.7 (1.1)	8 (0.0)	.49
Balance (four-stage balance)									
Stand balance	9.8 (1.0)	9.9 (0.8)	9.8 (1.1)	.09	9.8 (1.1)	9.8 (1.0)	10.0 (0.0)	10.0 (0.0)	.02
Semi tandem	9.7 (1.5)	9.5 (2.0)	9.7 (1.2)	.00	9.8 (1.2)	9.6 (1.7)	9.2 (2.1)	10.0 (0.0)	.00
Tandem stance	8.9 (2.6)	8.8 (2.8)	8.9 (2.5)	.06	9.5 (1.7)	8.6 (2.8)	6.7 (4.1)	6.8 (4.3)	.00
Single leg stance	6.0 (3.8)	6.6 (3.8)	5.8 (3.8)	.61	7.1 (3.5)	5.2 (3.8)	2.9 (3.6)	0.6 (0.8)	.00

Note. Physical Activity. BMI = Body Mass Index; ADL = Activities of Daily Living; IADL = Instrumental Activities of Daily Living.
$p < .05$ considered as significant.

anthropometric measures on balance ($\beta = .18$, $p < .001$). Effect of the anthropometric measures on balance is weak ($\beta = .18$, $p < .05$). SEM used in this study illustrated that the effect on physical activity on strength ($\beta = .61$, $p < .05$), anthropometric measures ($\beta = -.41$, $p < .05$), influence on strength for controlling balance ($\beta = .52$, $p < .05$) and physical function ($\beta = -.35$, $p < .05$) are on the expected directions. Age was directly influenced for strength ($\beta = -.36$, $p < .05$) and anthropometric measures ($\beta = -.65$, $p < .05$) to the negative direction as predicted.

Discussion

This study investigated the influence of physical activity and age on strength, anthropometric measures, balance and functional status of a group of community-dwelling older adults in Sri Lanka. Blair et al.'s (2001) physical activity behavior model and structural equation modeling (SEM) technique were used in the analysis. The majority of the participants (75%) were women. About 87% of the participants had secondary or higher education; consistent with the higher literacy rate (84%) of people in the country (World Bank, 2017). This high literacy rate provides the rationale for the observed higher complete and valid response rate of the participants in this study. Results indicated a significant direct effect of physical activity and age on strength and anthropometric measures, and a significant indirect effect of physical activity and age on balance and physical functions of older adults.

In this study we found somewhat "high" total mean score of MET/week of physical activity (3,229) compared to previously reported total mean score of 3050 MET/week of physical activity in older adults in Sri Lanka (Katulanda et al., 2013). However, vigorous leisure-time physical activity of the participants in our study was zero. According to Sjögren and Stjernberg (2010) physical activity needs and opportunities vary by gender, and men were more likely to report higher physical activity scores than women. Further, Milanović et al. (2013) reported an equal reduction of physical activity in both gender when getting older. Our findings, however,

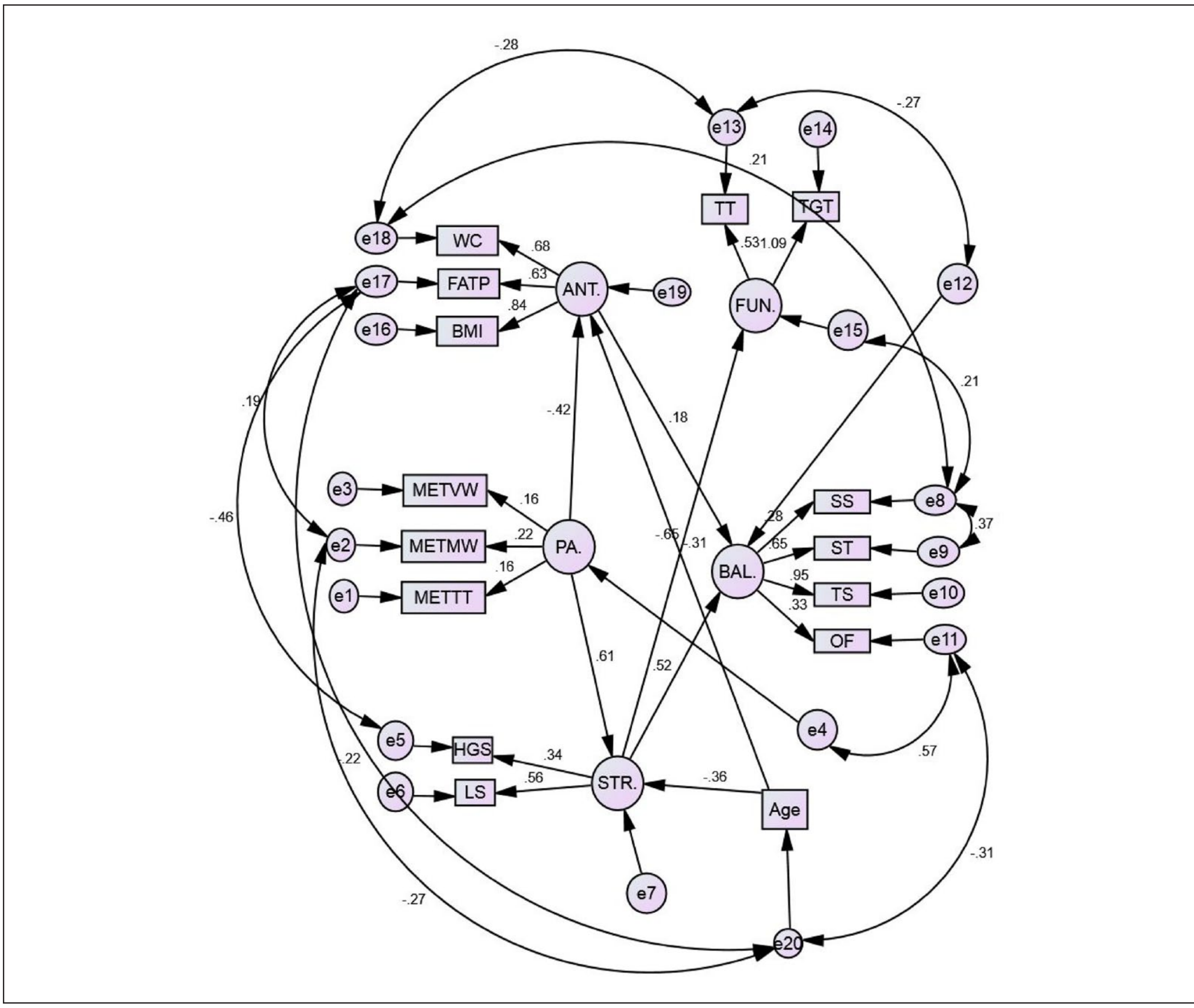

Figure 2. Structural Equation Model on the influence of Physical Activity and age for strength, anthropometric measures, balance and functional status of the community-dwelling older people in Sri Lanka. Diagram represents significant direct effects only.

Note. All effects in the figure are standardized regression coefficients. All coefficients were significant ($p < .05$). PA = Physical Activity; METVW = Vigorous work MET; METMW = Moderate work MET; TTMET = Total travel MET; STR = Strength; LS = leg strength; HGS = handgrip strength; ANT = Anthropometric measurements; WC = waist circumference; FAT*p* = fat percentage; BMI = Body mass index; BAL = Balance; SS = Stand; ST = Semi tandem; TS = Tandem stance; OF = Stand on one leg; FUN = Functional status; TT = 3,600 turning test; TGT = stand up and go test.

were somewhat different; older woman reported a higher physical activity score than that of older men. A vast majority of women in the country are somewhat confined to household chores and getting lack of opportunities to get leisure time physical activity. Men were also largely confined to work related activities and leisure time activities such as sports and exercises are not prevalent in them. Sri Lankan culture promotes religious activities during free times of the older adults, but not leisure time physical activities. Longitudinal studies are warranted in this area to understand the underpinnings of leisure time activities in Sri Lankan older adults.

The final SEM showed a good model fit. The model has a significant relationship between latent variables and covariances. The results were partially supported the hypothesized model, showing significant effects to all the predictors and correlations toward the expected directions, except the effect of anthropometric measures on balance. Physical activity and age seem to have direct impacts on strength and anthropometric measures, and indirect effects on balance and physical functions. In the model, the influence of leisure time activities on strength was not significant. Nevertheless, the results of the study suggest that strength is the main contributing factor for balance and good physical function in older adults in this target population. Physical activity, therefore can be considered as the modifiable behavioral factor which can be promoted to enhance strength of community-dwelling older adults in Sri Lanka.

The validity of the predictive model used in this study is supported by biological explanations of muscle power in humans. Quantitative loss of muscle mass and

Table 3. Estimated Standardized Regression Weight for the Validated Model.

Regression path	Regression weight (β)	p
Physical activity→Strength	.606	.000
Physical activity→Anthropometry	−.417	.000
Age→Anthropometry	−.312	.000
Age→Strength	−.361	.000
Strength→Balance	.525	.000
Anthropometry→Balance	.178	.000
Strength→Functional status	−.646	.000
Physical activity→Moderate work	.224	.000
Physical activity→Vigorous work	.163	.004
Balance→Stand	.283	.000
Balance→Semi tandem	.649	.000
Balance→Tandem stance	.945	.000
Balance→Stand on one leg	.325	.000
Functional status→360° turning test	.529	.000
Anthropometry→Body Mass Index	.838	.000
Anthropometry→Fat percentage	.625	.000
Anthropometry→Waist circumference	.679	.000
Physical activity→Travel	.157	.004
Strength→Hand grip strength	.344	.000
Strength→Leg strength	.562	.000
Functional status→Stand up and go test	1.092	

Note. $p \geq .01$ considered as significant.

alterations in the properties of individual muscle fibers influence the loss of muscle power in older people (Tieland et al., 2018). Aging affects all lower extremity compartments, and femoral muscle mass is the major compartment associated with physical function in older adults (Buford et al., 2012; Ferreira et al., 2012). In our study leg strength is a major component of total strength which is consistent with the previous studies (Ferreira et al., 2012). Even though there are many physiological mechanisms contributing to the lower extremity muscle power, physical activity plays a significant role in enhancing muscle power of the older adults (Langhammer et al., 2018; Reid et al., 2014). Our study supports the assertion that physical activity increases the lower extremity strength.

According to Milanović et al. (2013), after the age of 75 years, muscle strength decreases an average of 3.4% annually and this process can be slowed down through physical activity. Muscle strength loss is greater for lower limbs compared to upper limbs (Landers et al., 2001; Phillipe de Lucena Alves et al., 2022). Our study demonstrated that strength is reducing with increasing age and physical activity in old age tend to increase both hand grip strength and leg strength. So there is an overall increase of muscle strength in a physically active person compared to physically inactive person, showing a significant influence of work-related activities on strength.

Results of the impact of physical activity on anthropometric measures observed in this study were consistent with the studies conducted in diverse population groups. A study done in Florida, USA reported an association of both time spent in light intensity activity and lower sedentary times with lower BMI (Bann et al., 2015). High negative correlation was observed of physical activity with waist circumference (Ryu et al., 2013). Our study demonstrated that vigorous work, moderate work, and traveling would contribute to reduce fat percentage, BMI and waist circumference in older adults. Our study also found a gender difference of fat percentage; women reporting more fat percentage than the men as reported in a previous study (Silveira et al., 2021). Aging is associated with changes in the body composition including sarcopenia, and increasing total fat mass, and redistribution of body fat. These factors cause a relative reduction of subcutaneous fat mass (Caso et al., 2013). Further, it has been observed that there are age-related differences in subcutaneous fat in both the femoral and tibiofibular regions and these differences did not exist between the functionally distinct groups of older adults (Buford et al., 2012). Our study, however, indicated age-related significant reduction of the subcutaneous fat percentage, and the effect of this reduction on physical activity. The mechanism of subcutaneous peripheral fat loss with aging is not completely understood and further investigations are needed to understand these mechanism.

Our data suggest that there is a positive relationship between physical activity and balance performances as seen in other studies (Zouita et al., 2020). Dose-response effect of 3-days balance training activity tested for the group of older adults had shown 62% and 48% improvement of one leg stand in left and right (Bootsman et al., 2018). Cruz et al. (2017) found an association of upper limb functions for the balance performances. Our study has also shown a significant effect of age on balance decline, as had been reported in previous studies (Bootsman et al., 2018; Meunier et al., 2021). In our tested model, significant indirect influences of vigorous work, moderate work and travel on balance were identified. Blewitt and Chockalingam (2017) investigated the influence of traditional activities on balance and health outcomes, and observed extensive improvement of balance as a result of traditional activities prevai of a tested older group.

We observed a positive relationship between physical activity and functional performances of the older adults as has been reported in the literature (Daniel et al., 2010; Gogniat et al., 2022; Mullen et al., 2012). Better functional performances were associated with fewer functional limitations in later life (Jime et al., 2009; Mullen et al., 2012) and several studies reported a considerable influence of femoral muscle on physical function in older adults (Bootsman et al., 2018; Buford et al., 2012).

Strengths and Limitations

In this study we have used a large representative sample to investigate the possible relationships between the study variables. This is the first study conducted to investigate physical activity, fitness and functional outcome of the older adults in Sri Lanka, a middle income country in South Asia. The study assessed physical activity subjectively using a questionnaire rather than using objective measures such as accelerometers or pedometers which are considered more accurate and valid. There may be a considerable response bias in this type of study, another possible limitation in this study. Fat percentage and BMI were assessed using prediction equations methods rather than using more accurate technologies. The proportion of older women participated in the study was higher than that of older men. Older women are available in their homes during the day time because the majority of them are confined to household work, but older men, in general, go out of their homes for income generating activities during the day time. Further, the life expectancy of women (80.4 years) was higher than that of men (73.8 years) in the country and therefore women outnumber men in this target population. However, an adequate number of older men (220) participated in the study.

Conclusion

In conclusion, this study provides insight into the influence of physical activity and age on changing strength, balance, and physical function of community-dwelling older adults in Sri Lanka. Older women were found to be more physically active than older men, although the BMI and fat percentage in the body were relatively higher in older women compared to that of older men. Physical activity positively influences strength, balance and physical functions in older adults. The results of the study support for the implementation of muscle-strengthening geriatric care programs to enhance balance and functional performances of community-dwelling older adults in Sri Lanka.

The model that we have developed indicated the importance of promoting exercises which are specifically targeted at strengthening lower extremity power for better balance and functional performances in older adults. Work related activities is the prominent domain of physical activity in this target group. Results indicate that leisure time physical activities do not contribute to enhance strength, indicating that these activities should be more rigorous and readjusted so that they can effectively contribute to enhance strength of older adults. Further, leisure-time physical activity behaviors are vital for psychological well-being of older adults. Thus, community level awareness programs and provision of facilities are required to motivate older adults for leisure-time physical activity. Application of strength test (hand grip and leg strength) as a screening activity to predict potential risk of falls and development of functional disabilities of older adults in the community should be seriously considered by health authorities. In addition, further studies are needed to explore the other factors such as nutrition that contribute to physical strength. Old-age physical activity promotion programs should put more emphasis on enhancing strength, balance, and functional status of community-dwelling older adults in Sri Lanka for better results.

Acknowledgment

We acknowledge all the participants who participated voluntarily in this community survey research.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethical Approval

Ethical approval was obtained from the Ethics Committee of the Faculty of Allied Health Sciences, University of Ruhuna, Galle, Sri Lanka (12.07.2018: 3.1).

ORCID iD

Bilesha Perera https://orcid.org/0000-0001-5398-710X

Data Availability

The primary data can be provided upon request.

References

Asian Development Bank. (2019). *Growing older before becoming rich: Challenges of an aging population in Sri Lanka*. Asian Development Bank, Phillipines. http://doi.org/10.22617/TCS190612-2.

Bann, D., Hire, D., Manini, T., Cooper, R., Botoseneanu, A., McDermott, M. M., Pahor, M., Glynn, N. W., Fielding, R., King, A. C., Church, T., Ambrosius, W. T., & Gill, T. M. (2015). Correction: Light intensity physical activity and sedentary behavior in relation to body mass index and grip strength in older adults: Cross-sectional findings from the lifestyle interventions and independence for elders (LIFE) study. *PLoS One*, *10*, 1–13. https://doi.org/10.1371/journal.pone.0126063

Bentler, P. M., & Bonett, D. G. (1980). Significance Tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588–606. https://doi.org/10.1037/0033-2909.88.3.588

Blair, S. N., Cheng, Y., & Holder, J. S. (2001). Is physical activity or physical fitness more important in defining health benefits? *Medicine and Science in Sports and Exercise*, *33*(6 Suppl), S379–S399. https://doi.org/10.1097/00005768-200106001-00007

Blewitt, C. L., & Chockalingam, N. (2017). The role of “non-traditional” physical activities in improving balance in older adults: A review. *Journal of Human Sport and Exercise*, *12*(2), 446–462. https://doi.org/10.14198/jhse.2017.122.21

Bootsman, N. J. M., Skinner, T. L., Lal, R., Glindemann, D., Lagasca, C., & Peeters, G. M. E. E. (2018). The relationship between physical activity, and physical performance and psycho-cognitive functioning in older adults living in residential aged care facilities. *Journal of Science and Medicine in Sport*, *21*(2), 173–178. https://doi.org/10.1016/j.jsams.2017.07.006

Buford, T. W., Lott, D. J., Marzetti, E., Wohlgemuth, S. E., Vandenborne, K., Pahor, M., Leeuwenburgh, C., & Manini, T. M. (2012). Age-related differences in lower extremity tissue compartments and associations with physical function in older adults. *Experimental Gerontology*, *47*(1), 38–44. https://doi.org/10.1016/j.exger.2011.10.001

Caso, G., McNurlan, M. A., Mileva, I., Zemlyak, A., Mynarcik, D. C., & Gelato, M. C. (2013). Peripheral fat loss and decline in adipogenesis in older humans. *Metabolism*, *62*(3), 337–340. https://doi.org/10.1016/j.metabol.2012.08.007

Cruz, D. M. C. D., Lima, T. D. C., Nock, L. J., Figueiredo, M. D. O., & Paulisso, D. C. (2017). Relationships between falls, age, independence, balance, physical activity, and upper limb function in elderly Brazilians. *Cogent Medicine*, *4*, 1. https://doi.org/10.1080/2331205X.2017.1367058

Daniel, F., Vale, R., Giani, T., Bacellar, S., & Dantas, E. (2010). Effects of a physical activity program on static balance and functional autonomy in elderly women. *Macedonian Journal of Medical Sciences*, *3*(1), 21–26. https://doi.org/10.3889/mjms.1857-5773.2010.0083

Durnin, J. V., & Womersley, J. (1974). Body fat assessed from total body density and its estimation from skinfold thickness: Measurements on 481 men and women aged from 16 to 72 years. *The British journal of nutrition*, *32*(1), 77–97. https://doi.org/10.1079/bjn19740060

Elam, C., Aagaard, P., Slinde, F., Svantesson, U., Hulthén, L., Magnusson, P. S., & Bunketorp-Käll, L. (2021). The effects of ageing on functional capacity and stretch-shortening cycle muscle power. *Journal of Physical Therapy Science*, *33*(3), 250–260. Epub 2021 Mar 17. https://doi.org/10.1589/jpts.33.250

Ferreira, M. L., Sherrington, C., Smith, K., Carswell, P., Bell, R., Bell, M., Nascimento, D. P., Máximo Pereira, L. S., & Vardon, P. (2012). Physical activity improves strength, balance and endurance in adults aged 40–65 years: A systematic review. *Journal of Physiotherapy*, *58*(3), 145–156. https://doi.org/10.1016/s1836-9553(12)70105-4

Gogniat, M. A., Robinson, T. L., Jean, K. R., & Stephen Miller, L. (2022). Physical activity moderates the association between executive function and functional connectivity in older adults. *Aging Brain*, *2*, 100036. https://doi.org/10.1016/j.nbas.2022.100036

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *Lancet*, *380*(9838), 247–257. https://doi.org/10.1016/s0140-6736(12)60646-1

Jime, R., Garatachea, N., Molinero, O., Martı, R., Ma, S., & Gonza, J. (2009). Feelings of well being in elderly people: Relationship to physical activity and physical function. *Archives of Gerontology and Geriatrics*, *48*, 306–312. https://doi.org/10.1016/j.archger.2008.02.0102009.

Katulanda, P., Jayawardena, R., Ranasinghe, P., Rezvi Sheriff, M. H., & Matthews, D. R. (2013). Physical activity patterns and correlates among adults from a developing country: The Sri Lanka Diabetes and Cardiovascular Study. *Public Health Nutrition*, *16*(9), 1684–1692. https://doi.org/10.1017/S1368980012003990

Landers, K. A., Hunter, G. R., Wetzstein, C. J., Bamman, M. M., & Weinsier, R. L. (2001). The interrelationship among muscle mass, strength, and the ability to perform physical tasks of daily living in younger and older women. *Journal of Gerontology*, *56*(10), 443–448. https://doi.org/10.1093/gerona/56.10.b443

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*(1), 159–174.

Langhammer, B., Bergland, A., & Rydwik, E. (2018). The importance of physical activity exercise among older people. *BioMed Research International*, *2018*, 7856823. https://doi.org/10.1155/2018/7856823

Mesquita, L. S. D. A., de Carvalho, F. T., Freire, L. S. D. A., Neto, O. P., & Zângaro, R. A. (2015). Effects of two exercise protocols on postural balance of elderly women: A randomized controlled trial. *BMC Geriatrics*, *15*(1), 61.

Meunier, C. C., Smit, E., Fitzpatrick, A. L., & Odden, M. C. (2021). Balance and cognitive decline in older adults in the cardiovascular health study. *Age and Ageing*, *50*(4), 1342–1348. https://doi.org/10.1093/ageing/afab038

Milanović, Z., Pantelić, S., Trajković, N., Sporiš, G., Kostić, R., & James, N. (2013). Age-related decrease in physical activity and functional fitness among elderly men and women. *Clinical Interventions in Aging*, *8*, 549–556. https://doi.org/10.2147/CIA.S44112

Mullen, S. P., McAuley, E., Satariano, W. A., Kealey, M., & Prohaska, T. R. (2012). Physical activity and functional limitations in older adults: The influence of self-efficacy and functional performance. *Journal of Gerontololy: Series B Psychological and Social Scicences, 67B*(3), 354–361. https://doi.org/10.1093/geronb/gbs036

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., Macera, C. A., & Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise*, *39*(8), 1435–1445. https://doi.org/10.1249/mss.0b013e3180616aa2

Phillipe de Lucena Alves, C., Câmara, M., Dantas Macêdo, G. A., Freire, Y. A., de Melo Silva, R., Paulo-Pereira, R., Farias-Junior, L. F., Fayh, A. P. T., Mortatti, A. L., & Costa, E. C. (2022). Agreement between upper and lower limb measures to identify older adults with low skeletal muscle strength, muscle mass and muscle quality. *PLoS One*, *17*(1), e0262732. https://doi.org/10.1371/journal.pone.0262732

Reid, K. F., Pasha, E., Doros, G., Clark, D. J., Patten, C., Phillips, E. M., Frontera, W. R., & Fielding, R. A. (2014). Longitudinal decline of lower extremity muscle power in healthy and mobility-limited older adults: Influence of muscle mass, strength, composition, neuromuscular activation and single fiber contractile properties. *European Journal of Applied Physiology*, *114*, 29–39. https://doi.org/10.1007/s00421-013-2728-2

Ryu, M., Jo, J., Lee, Y., Chung, Y. S., Kim, K. M., & Baek, W. C. (2013). Association of physical activity with sarcopenia and sarcopenic obesity in community-dwelling older adults: The fourth Korea National Health and Nutrition Examination Survey. *Age and Ageing*, *42*, 734–740. https://doi.org/10.1093/ageing/aft063

Silveira, E. A., Barbosa, L. S., Noll, M., Pinheiro, H. A., & de Oliveira, C. (2021). Body fat percentage prediction in older adults: Agreement between anthropometric equations and DXA. *Clinical Nutrition*, *40*(4), 2091–2099. https://doi.org/10.1016/j.clnu.2020.09.032

Siriwardhana, D. D., Walters, K., Rait, G., Bazo-Alvarez, J. C., & Weerasinghe, M. C. (2018). Cross-cultural adaptation and psychometric evaluation of the Sinhala version of Lawton instrumental activities of daily living scale. *PLoS One*, *13*(6), e0199820. https://doi.org/10.1371/journal.pone.0199820

Sjögren, K., & Stjernberg, L. (2010). A gender perspective on factors that influence outdoor recreational physical activity among the elderly. *BMC Geriatrics*, *10*, 34. https://doi.org/10.1186/1471-2318-10-34

Stavrinou, P. S., Aphamis, G., Pantzaris, M., Sakkas, G. K., & Giannaki, C. D. (2022). Exploring the associations between functional capacity, cognitive function and well-being in older adults. *Life*, *12*, 1042. https://doi.org/10.3390/life12071042

Tieland, M., Trouwborst, I., & Clark, B. C. (2018). Skeletal muscle performance and ageing. *Journal of Cachexia Sarcopenia and Muscle*, *9*(1), 3–19. https://doi.org/10.1002/jcsm.12238

Trombetti, A., Reid, K. F., Hars, M., Herrmann, F. R., Pasha, E., Phillips, E. M., & Fielding, R. A. (2016). Age-associated declines in muscle mass, strength, power, and physical performance: Impact on fear of falling and quality of life. *Osteoporosis International*, *27*(2), 463–471.

Tse, M. M., Vong, S. K., & Tang, S. K. (2013). Motivational interviewing and exercise programme for community-dwelling older persons with chronic pain: A randomised controlled study. *Journal of Clinical Nursing*, *22*(13-14), 1843–1856. https://doi.org/10.1111/j.1365-2702.2012.04317.x

Tse, M. M., Wan, V. T., & Ho, S. S. (2011). Physical exercise: Does it help in relieving pain and increasing mobility among older adults with chronic pain? *Journal of Clinical Nursing*, *20*(5-6), 635–644. https://doi.org/10.1111/j.1365-2702.2010.03548.x

Tyndall, A. V., Clark, C. M., Anderson, T. J., Hogan, D. B., Hill, M. D., Longman, R. S., & Poulin, M. J. (2018). Protective Effects of exercise on cognition and Brain Health in Older Adults. *Exercise and Sport Sciences Reviews*, *46*(4), 215–223. https://doi.org/10.1249/jes.0000000000000161

United Nations. (2022). Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Summary of Results. UN DESA/POP/2022/TR/NO. 3. https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf

Volaklis, K. A., Halle, M., & Meisinger, C. (2015). Muscular strength as a strong predictor of mortality: A narrative review. *European Journal of Internal Medicine*, *26*(5), 303–310. https://doi.org/10.1016/j.ejim.2015.04.013

Wannamethee, S. G., & Atkins, J. L. (2019). Muscle loss and obesity: The health implications of sarcopenia and sarcopenic obesity. *Proceedings of The Nutrition Society*, *74*, 405–412. https://doi.org/10.1017/S002966511500169X

Wickramarachchi, B., Siop, S., & Perera, B. (2021). Sinhalese version of the global physical activity questionnaire for community-dwelling older adults: Reliability and validity. *Aging and Health Research*, *1*(2), 2667–0321. https://doi.org/10.1016/j.ahr.2021.100016

World Bank. (2017). Sri Lanka development update, June 2017, (June), 1–38. https://openknowledge.worldbank.org/bitstream/handle/10986/27519/116949-WP-P153384-PUBLIC-Sri-Lanka-Development-Update-Spring-2017.pdf?sequence=5&isAllowed=y

World Health Organization. (2007). *WHO Global Report on Falls Prevention in Older Age* (pp. 20–25). Ageing And Life Course, Family And Community Health. https://extranet.who.int/agefriendlyworld/wp-content/uploads/2014/06/WHo-Global-report-on-falls-prevention-in-older-age.pdf

World Health Organization. (2021). Global physical activity questionnaire. *World Health Organization*. https://www.who.int/docs/default-source/ncds/ncd-surveillance/gpaq-analysis-guide.pdf?sfvrsn=1e83d571_2

World Health Organization. (2022). *Aging and health*. Author. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health.

Zouita, S., Zouhal, H., Ferchichi, H., Paillard, T., Dziri, C., Hackney, A. C., Laher, I., Granacher, U., & Ben Moussa Zouita, A. (2020). Effects of combined balance and strength training on measures of balance and muscle strength in older women with a history of Falls. *Frontiers in Physiology*, *11*, 619016. https://doi.org/10.3389/fphys.2020.619016