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Artikel Asli/*Original Articles*

The Association between Physical Fitness with Successful Ageing and Risk of Cognitive Impairment among Malaysian Older Adults

(Hubungan antara Kecergasaan Fizikal dengan Penuaan Berjaya dan Kecelaan Kognitif Ringan dalam Kalangan Warga Emas Malaysia)

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ABSTRACT

The expansion of ageing population has gained much public attention on the importance of healthy and successful ageing, which is absence of major chronic diseases, preserved physiological and cognitive functioning and active engagement with life. Previous studies have found there was a significant correlation between physical fitness with cognition. However, the relationship between physical fitness with successful and unsuccessful cognitive ageing groups are very limited. This study was aimed to identify the significant physical fitness components that contribute in reducing risk of cognitive decline represented as different cognitive ageing groups. A total of 300 community-based elderly aged 60 and above from the states of Selangor, Perak and Kelantan were recruited using multistage random sampling method in this cross-sectional study. Cognitive function of subjects was categorized into three groups, namely Mild Cognitive Impairment (MCI) (n = 100), Usual Ageing (UA) (n = 100) and Successful Ageing (SA) (n = 100) based on defined criteria. Senior Fitness Tests included 2-minute step, handgrip strength, chair stand, chair sit-and-reach, 8 foot up-and-go and back scratch were measured to determine the cardiorespiratory fitness; muscle strength; agility and flexibility of subjects. SA group had significantly better performance than non-SA groups in all fitness components, except for chair sit-and-reach. After controlling for age, gender, education years and smoking status, handgrip strength and chair stand tests were associated with a reduced risk of MCI by 7% [OR: 0.93, 95% C.I: 0.88-0.99, p < 0.05] and 15% [OR: 0.85, 95% C.I: 0.75-0.95, p < 0.01], respectively. These findings suggest that older adults with higher upper and lower body muscular strength could serve as protective factors for cognitive impairment. Further research is warranted to evaluate the mechanism of physical and cognitive decline such as Motoric Cognitive Risk Syndrome (MCR) in more detailed for the purpose for promoting healthy and successful ageing.

Keywords: Successful ageing; physical fitness; cognitive function; mild cognitive impairment; muscular strength

ABSTRAK

Perkembangan populasi penuaan telah menimbulkan banyak perhatian orang ramai terhadap kepentingan penuaan sihat dan berjaya, iaitu ketiadaan penyakit kronik utama, fungsi fisiologi dan kognitif dipelihara serta penglibatan aktif dalam kehidupan. Kajian terdahulu mendapati bahawa terdapat hubungan yang signifikan antara kecergasan fizikal dengan fungsi kognitif. Walau bagaimanapun, hubungan antara kecergasan fizikal dengan kumpulan penuaan kognitif berjaya dan tidak berjaya adalah sangat terhad. Kajian ini bertujuan untuk mengenal pasti komponen kecergasan fizikal signifikan yang menyumbang kepada penurunan risiko fungsi kognitif yang diwakili sebagai kumpulan penuaan kognitif yang berbeza. Seramai 300 warga tua berasaskan komuniti yang berumur 60 tahun ke atas dari negeri Selangor, Perak dan Kelantan telah direkrut dengan menggunakan kaedah pensampelan rawak berbilang tingkat dalam kajian hirisan lintang ini. Fungsi kognitif subjek dikategorikan kepada tiga kumpulan, iaitu Kecelaan Kognitif Ringan (MCI) (n = 100), Penuaan Biasa (UA) (n = 100) dan Penuaan Berjaya (SA) (n = 100) berdasarkan kriteria yang ditetapkan. Ujian Kecergasan Warga Emas termasuk 2-minutes step, kekuatan genggaman tangan, chair stand, chair sit-and-reach, 8 foot up-and-go danback scratchdiukur bagi menentukan kecergasan kardiorespiratori; kekuatan otot; ketangkasan dan kelenturan subjek. Kumpulan SA mempunyai prestasi yang lebih baik daripada kumpulan bukan SA dalam semua komponen kecergasan, kecuali chair sit-and-reach. Selepas kawalan bagi faktor umur, jantina, tahun pendidikan dan status merokok, ujian kekuatan genggaman tangan dan chair stand berhubung kait dengan penurunan risiko MCI sebanyak 7% [OR: 0.93, 95% CI: 0,88-0,99, p < 0.05] dan 15% [OR 0.85, 95% CI: 0,75-0,95, p < 0.01] secara masing-masing. Hasil kajian ini menunjukkan bahawa warga emas yang mempunyai kekuatan otot bahagian atas dan bawah tubuh yang lebih tinggi mampu bertindak sebagai faktor pelindung bagi kemerosotan fungsi kognitif. Kajian lanjutan diperlukan untuk menilai mekanisme kemerosotan fungsi fizikal dan kognitif seperti sindrom Risiko Motorik Kognitif (MCR) dengan lebih terperinci bagi tujuan menggalakkan penuaan sihat dan berjaya.

Kata kunci: Penuaan berjaya; kecergasan fizikal; fungsi kognitif; kecelaan kognitif ringan; kekuatan otot

INTRODUCTION

Ageing is not a disease but a normal physiological process resulting from accumulation of cellular components damage included protein, DNA and cell membrane (Yeoman et al. 2012). Normal ageing can be further categorized into usual ageing (UA) and successful ageing (SA) (Rowe and khan 1965). Successful ageing can be defined as absence of major chronic diseases (high blood pressure, diabetes, cancer, chronic lung disease, congestive heart failure and stroke), preserved psychocognitive and physical functioning (Hamid et al. 2012). Mild cognitive Impairment (MCI) is known to be the intermediate stage between ageing and dementia. Older adults with MCI have higher risk in developing dementia (Burns & Zaudig 2002).

Physical and cognitive functions are indicators of both normal ageing and functional decline occurred gradually with increasing of age. Older adults often accompanied with weak muscle strength, poor memory and delayed in solving cognitive tasks when compared to younger adults (Clouston et al. 2013). Abnormal physical and cognitive decline may occur in some individuals and these lead to loss of functional independence, decreased quality of life and increased the risk of frailty and falls (Cooper et al. 2011; Studenski et al. 2011; Tomey & Sowers 2009).

Older adults with better movement, balance, muscle strength and aerobic fitness have better cognitive function (Blankevoort et al. 2013; Volker & Scherder 2014). Poor physical function among older adults accelerated the rate of cognitive decline as well as increased the risk of dementia (Sattler et al. 2011). Previous study reported that poor cognitive performance could be predicted by physical fitness among Malaysian older adults (Won et al. 2014). Therefore, physical fitness is important in preserving the physical and cognitive functions among older adults. However, there is a lack of evidence on association between physical fitness with successful ageing and the risk of getting cognitive impairment that represented by different ageing groups. Thus, this study is aimed to compare the functional fitness between different ageing groups and determine their associations with successful ageing as well as the risk of mild cognitive impairment.

EXPERIMENTAL METHODS

STUDY DESIGN, SUBJECTS AND SAMPLING

A total of 300 older adults aged 60 years and above consisted 186 males and 114 females were involved in this cross-sectional comparative study. The sample size was calculated using G*Power (Faul et al. 2007) software with medium effect size (f) at 0.20 and while the power (1 - β) is 0.80. Subjects with MCI (n = 100) were randomly drawn from a larger community-based longitudinal study reported earlier (Shahar et al. 2015). With age- and gender-matched, subjects with UA (n= 100) and SA (n = 100) were drawn from the same cohort. This study was approved by the Research Ethics Committee with reference number UKM 1.5.3.5/244/NN-060-2013 and informed consent was obtained from all the subjects.

COGNITIVE AGEING GROUPS CLASSIFICATION

The details of cognitive ageing groups classification protocol have been previously published (Shahar et al. 2015). Briefly it was done based on multidimensional domains included physical function, subjective and objective memory impairments, psychocognitive functioning, major diseases, health status and quality of life by using pretested questionnaires.

PHYSICAL FITNESS ASSESSMENTS

Senior Fitness Tests (SFT) was introduced by Jones and Rikli (2002) to evaluate the physical fitness among older adults, included cardiorespiratory fitness, upper and lower body muscular strength, flexibility, dynamic balance and agility:

1. 2-minutes step was used to assess cardiorespiratory fitness,
2. Handgrip strength was measured by digital hand dynamometer (Jamar® Plus+, Patternson Medical, Illinois, USA) to assess upper body muscular strength,
3. Lower body muscular strength was assessed using chair stand test,
4. The lower body flexibility was assessed using chair sit-and-reach test,
5. 8 foot up-and go was used to assess agility and balance,
6. Back scratch was used to assess upper body flexibility.
7. All the detailed protocols have been described and published (Shahar et al. 2015).

STATISTICAL ANALYSIS

The statistical analysis of this study was carried out using Statistical Package for Social Science (SPSS) version 22. Significant value was set at $p < 0.05$. Socio-demographic data and physical fitness of the subjects between SA, UA and MCI were compared using $\chi 2$ tests for categorical variables and results are presented as number (percentage). One-way Analysis of Variance (ANOVA) test was used to analyse continuous variable. Results are presented as mean ± standard deviation for normally distributed data and median (quartile range) for data that were not normally distributed. LSD post hoc test was used to compare the significant difference of continuous variables between groups. Correlations between physical fitness with global cognitive function as assessed by MMSE were determined using bivariate analysis. Odds of MCI and UA were estimated using multivariate analysis that was Multinomial Logistic Regression. Covariates such as age, gender, educational years and smoking status were also included in the analysis. Non-parametric tests such as Kruskal-Wallis and Spearman's correlation were used when the variables were not normally distributed.

RESULTS

Table 1 summarizes the socio-demographic characteristics of the 300 subjects. The mean age of subjects was 68.04 ± 5.56 year-old, and there was no significant difference between ageing groups ($p > 0.05$). Majority of the subjects in this study were Malays (61.3%), followed by Chinese (35.7%) and only 3.0% were Indians. Ethnic also had no significant difference in this study ($p > 0.05$). A total of 67.7% subjects received education less than 6 years and only 32.3% received education more than 6 years, and it showed a significant difference between ageing groups ($p < 0.001$). No significant difference was found in smoking habit among subjects in the three ageing groups.

Table 2 shows the comparison of physical fitness between three ageing groups. Older adults with successful ageing perform better in Senior Fitness Tests as compared to those with usual ageing and MCI. Subjects in MCI group had significantly lower cardiorespiratory fitness as assessed by 2-minutes step test (60.00 ± 25.24) compared to those in UA (67.05 ± 20.44) and SA groups (73.75 ± 26.20) ($p < 0.001$). Handgrip strength also significantly higher among those in SA group (26.03 ± 7.23 kg) than MCI group (23.04 ± 7.40 kg) ($p < 0.01$). A significant better performance in chair stand test can be observed in SA group (11.37 ± 3.22) than in UA (9.71 ± 2.43) and MCI groups (9.33 ± 3.02) ($p < 0.001$). Subjects in SA group also had significantly better agility and balance as assessed using 8 foot up-and-go test (9.96 ± 3.74 s) than UA (11.04 ± 3.09 s) and MCI groups (12.30 ± 6.78 s) ($p < 0.001$). Better upper body flexibility as assessed using back scratch test can also be observed among subjects in SA group (11.89 ± 12.80 cm) compared to UA (15.75 ± 11.98 cm) and MCI groups (18.05 ± 15.57 cm) ($p < 0.01$). In contrast, chair sit-and-reach test had no significant difference between different ageing groups ($p > 0.05$).

Table 3 shows bivariate correlation analysis of the associations between physical fitness and global cognitive function as assessed using Mini Mental State Examination (MMSE). 2-minutes step ($r = 0.32$), handgrip strength (r = 0.26) and chair stand ($r = 0.29$) were positively associated with MMSE ($p < 0.001$). A better performance in the 8

TABLE 1. Socio-demographic characteristics

Parameter	SA (n = 100)	UA (n = 100)	MCI (n = 100)	Total (N =300)	p^a
Age	67.99 ± 5.52	68.00 ± 5.57	68.14 ± 5.64	68.04 ± 5.56	> 0.05
Ethnic					
Malay	61 (33.2)	61 (33.2)	62 (33.7)	184 (61.3)	
Chinese	36 (33.6)	36 (33.6)	35 (32.7)	107 (35.7)	> 0.05
Indian	3 (33.3)	3 (33.3)	3 (33.3)	9 (3.0)	
Marriage Status					
Single/Widow/Widower/Divorced	17 (17.0)	19 (19.0)	25 (25.0)	61 (20.3)	> 0.05
Married	83 (83.0)	81 (81.0)	75 (75.0)	239 (79.7)	
Educational Year					
≤ 6 years	44 (44.0)	78 (78.0)	81 (81.0)	203 (67.7)	< 0.001
> 6 years	56 (56.0)	22 (22.0)	19 (19.0)	97 (32.3)	
Smoking Habit					
Smoking	20 (20.0)	20 (20.0)	26 (26.0)	66 (22.0)	> 0.05
Past or non-smokers	80 (80.0)	80 (80.0)	74 (74.0)	234 (78.0)	

SA: Successful Ageing; UA: Usual Ageing; MCI: Mild Cognitive Impairment, Chi-Squared test, significant at $p < 0.01$, [a]One-way ANOVA (mean ± standard deviation), not significant at $p > 0.05$

TABLE 2. Comparison of physical fitness between ageing groups

Parameter	SA (n = 100)	UA (n = 100)	MCI (n = 100)	p
Cardiorespiratory fitness: 2-minutes step test (repetition)	73.75 ± 26.20	67.05 ± 20.44	60.00 ± 25.24	< 0.001[*#]
Upper body muscular strength: Handgrip strength test/kg	26.03 ± 7.23	24.17 ± 7.23	23.04 ± 7.40	< 0.01[*]
Lower body muscular strength: Chair stand test (repetition)	11.37 ± 3.22	9.71 ± 2.43	9.33 ± 3.02	< 0.001[*^]
Lower body flexibility: Chair sit-and-reach test/cm	-2.00 (12.40)	-1.20 (11.25)	-1.00 (19.13)	> 0.05
Agility and balance: 8 foot up-and-go test/s	9.96 ± 3.74	11.04 ± 3.09	12.30 ± 6.78	< 0.001[*^]
Upper body flexibility: Back scratch test/cm	11.89 ± 12.80	15.75 ± 11.98	18.05 ± 15.57	< 0.01[*^]

SA: Successful Ageing; UA: Usual Ageing; MCI: Mild Cognitive Impairment**,** One-way ANOVA and pos hoc test LSD**,** [#]Significant between MCI and UA**,** [*]Significant between MCI and SA**,** [^]Significant between UA and SA**,** [a] Krurskal-Wallis test, not significant at $p > 0.05$

TABLE 3. Associations between physical fitness with global cognitive function

Parameter	Global Cognitive Function (MMSE)	
	r	*p*
Cardiorespiratory fitness	0.32	< 0.001
Upper body muscular strength	0.26	< 0.001
Lower body muscular strength	0.29	< 0.001
Lower body flexibility	-0.02	> 0.05[a]
Agility and balance	-0.27	< 0.001
Upper body flexibility	-0.17	< 0.01

MMSE: Mini Mental State Examination, Pearson correlation, significant at $p < 0.01$, [a] Spearman's correlation, not significant at $P > 0.05$

TABLE 4. Significant physical fitness determinants of cognitive impairment

	Parameter	B	Exp (B)	95 % C.I		*p*
				Upper	Lower	
MCI	Upper body muscular strength	-0.07	0.93	0.88	0.99	< 0.05
	Lower body muscular strength	-0.15	0.85	0.75	0.95	< 0.01
UA	Upper body muscular strength	-0.04	0.96	0.91	1.02	> 0.05
	Lower body muscular strength	-0.13	0.88	0.79	0.98	< 0.05

MCI: Mild Cognitive Impairment; UA: Usual Ageing, Multinomial logistic regression forward entry method controlled for age, gender, education years and smoking status, significant at $p < 0.01$, The reference group is Successful Ageing (SA).

foot up-and-go ($r = -0.27$; $p < 0.001$) and back scratch ($r = -0.17$; $p < 0.01$) tests represented by shorter distance was also found significantly associated with higher MMSE scores. Although significant associations were observed, however the output of association are rather weak. Chair sit-and-reach test had no significant association with global cognitive function ($p > 0.05$).

Table 4 shows the significant physical fitness determinants of cognitive impairment through multivariate analysis. Fitness parameters that were significant in the univariate analysis were included in multivariate logistic regression model with forward entry method to determine the level of importance of each predictor variables. After controlled for age, gender, education years and smoking status, the present study found that older adults with higher upper and lower body muscular strength have reduction of 7 % for MCI [OR: 0.93, 95% C.I: 0.88-0.99, $p < 0.05$] and 15% [OR: 0.85, 95% C.I: 0.75-0.95, $p < 0.01$] respectively. Older adults with higher lower body muscular strength also had 12% lower risk of having usual ageing as compared to successful ageing individuals [OR: 0.88, 95% C.I: 0.79-0.98, $p < 0.05$]. In other words, those subjects who had higher muscular strength were more likely to have successful ageing.

DISCUSSION

In this cross-sectional comparative study, older adults with successful ageing (SA) had better cardiorespiratory fitness, lower and upper body muscular strength, upper body flexibility, agility and balance compared to the older adults with usual ageing (UA) and mild cognitive impairment (MCI). According to the study conducted by Lin et al. (2016), older adults in SA group also performed better in handgrip strength and timed up-and-go test than those in non-SA group. This indicated that older adults with better muscular strength, agility and dynamic balance performance exhibit higher physical functioning and independence in performing daily living activities; therefore they are more able to achieve SA. In addition, chair sit-and-reach test also had no significant difference between SA group and non-SA group. The possible reason is that joint motion is closely related with physical functioning than flexibility. Poor flexibility may not represent limited joint motion, but it rather affects the physical functioning and independence. Study conducted by Lee et al. (2016) to evaluate the relationship between SFT and cognitive function also reported that upper body flexibility as assessed using back scratch test and agility as assessed using 8 foot up-and-go were better among older adults without MCI compared to those with MCI. Fujiwara et al. (2013) also revealed that higher grip strength was observed among subjects with normal cognition as compared to subjects with MCI. Similar to the study conducted by Lin et al. (2016), this finding implicated that higher grip strength contributed into better functional independence of older adults and they are more favourable to normal cognitive function.

The present study findings are also consistent with earlier research conducted by Han and Kang (2015) in which the muscular strength and endurance, flexibility, agility and cardiorespiratory fitness were significantly associated with MMSE score. MMSE score had been reported significantly higher in highest quartile of handgrip strength than lowest quartile in the study conducted by Jang and Kim (2015). Ahn and Kang (2015) also revealed that agility as assessed using 8-foot up-and-go could act as a predictive factor of global cognitive function.

The multivariate logistic model found that higher muscular strength in upper and lower body could reduce the risk of cognitive impairment. Previous study conducted by Lin et al. (2016) showed evidence that individuals with moderate or high fitness level were less likely to have MCI as compared to those with low physical fitness level. Fujiwara et al. (2013) reported that weak handgrip strength was positively associated with increased risk of MCI. Lin et al. (2016) also reported that handgrip strength and agility were positively associated with successful ageing.

Similar with cross-sectional studies, prospective studies also shows significant relationships between poor physical fitness with cognitive impairment. According to the study conducted by Boyle et al. (2009), increased muscular strength was associated with decreased rate in cognitive impairment. In addition, muscular strength was also associated with reduced risk in MCI among community dwelling older adults. A four years follow-up longitudinal study carried out by Auyeung et al. (2011) also showed that poor performance in handgrip strength and chair-stand test was positively associated with cognitive impairment among older adults. Subjects in lowest quartile of grip strength also had significant cognitive impairment than those in highest quartile in the study conducted by Alfaro-Acha et al. (2006).

A few studies that have been discussed above involved the determination of MCI based on MMSE (Jang & Kim 2015; Lee et al. 2016) and MoCa (Fujiwara et al. 2013) assessments only. However, none of the above-mentioned studies defined the MCI based on Peterson criteria (2014). Besides, only one research studied the association between physical fitness and successful ageing (Lin et al. 2016), and it is largely comparable with the present study. In addition, only a few studies applied the complete SFT (Han & Kang 2015; Lee et al. 2016; Lin et al. 2016), and most of the studies using handgrip strength as one of the potential markers of cognitive function deterioration. Senior Fitness Tests (SFT) was chosen because it is convenient to carry out in community setting (Lin et al. 2016) and handgrip strength is often used to represent the muscular strength of whole body (Jang & Kim 2015). Assessment of functional fitness through a variety of physical fitness test has higher validity and reliability than self-reported physical activity. Physical fitness tests could be used to assess physical function decline (Goldman et al. 2014) and it is also suggested that the measurement of physical fitness enables early detection of decline in physical function among older adults (Reuben et al. 2004).

Ageing process not only involved decline in cognitive function, but also physical function. Considering the nature of cross-sectional study, however, it remains unclear whether the measurement of muscle strength or other physical function is a strong predictor for the deterioration of cognitive function or vice versa (Taekema et al. 2010). Therefore, additional research is warranted to study the mechanism of physical and cognitive functions such as Motoric Risk Cognitive (MCR) syndrome in more detailed for the purpose of promoting healthy and successful ageing among older adults.

CONCLUSION

In this study we found that higher physical fitness especially lower muscular strength could reduce the risk of cognitive impairment and older adults were more likely to have successful ageing. Therefore, it is necessary to incorporate the physical fitness components especially muscular strength in daily physical activities in order to promote healthy and successful ageing among elderly population.

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REFERENCES

Ahn, J.D. & Kang, H. 2015. Physical fitness and serum vitamin D and cognition in elderly Koreans. *Journal of Sports Science and Medicine* 14(4): 740-746.

Auyeung, T.W., Lee, J.S.W., Kwok, T. & Woo, J. 2011. Physical frailty predicts future cognitive decline-A four-year prospective study in 2737 cognitively normal older adults. *Journal of Nutrition, Health & Aging* 15(8): 690-694.

Blankevoort, C.G., Scherder, E.J., Wieling, M.B., Hortobágyi, T., Brouwer, W.H., Geuze, R.H., van Heuvelen, M.J. 2013. Physical predictors of cognitive performance in healthy older adults: a cross-sectional analysis. *PLoS One* 8(7): 70799.

Boyle, P. A., Buchman, A. S., Wilson, R. S., Leurgans, S. E. & Bennett, D. A. 2009. Association of muscle strength with the risk of Alzheimer disease and the rate of cognitive decline in community-dwelling older persons. *Archives of Neurology & Psychiatry* 66(11): 1339-1344.

Burns, A. & Zaudig, M. 2002. Mild cognitive impairment in older people. *The Lancet* 360: 1963-1965.

Clouston, S. A. P., Brewster, P., Kuh, D., Richards, M., Cooper, R., Hardy, R., Rubin, M. S. & Hofer, S. M. 2013. The Dynamic Relationship Between Physical Function and Cognition in Longitudinal Aging Cohorts. *Epidemiologic Reviews* 35(1): 33-50.

Cooper, R., Kuh, D., Cooper, C., Gale, C. R., Lawlor, D. A., Matthews, F. & Hardy, R. 2011. Objective measures of physical capability and subsequent health: a systematic review. *Age and Ageing* 40(1): 14-23.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. 2007. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods* 39: 175-191.

Fujiwara, Y., Suzuki, H., Kawai, H., Hirano, H., Yoshida, H., Kojima, M., Ihara, K. & Obuchi, S. 2013. Physical and sociopsychological characteristics of older community residents with mild cognitive impairment as assessed by the Japanese version of the Montreal Cognitive Assessment. *Journal of Geriatric Psychiatry and Neurology* 26(4): 209-220.

Goldman, N., Glei, D.A., Rosero-Bixby, L., Chiou, S.T. & Weinstein, M. 2014. Performance-based measures of physical function as mortality predictors: Incremental value beyond self-reports. *Demographic Research* 30(7): 227-252.

Hamid, T.A., Momtaz, Y.A. & Ibrahim, R. 2012. Predictors and prevalence of successful aging among older Malaysians. *Gerontology* 58(4):366-370.

Han, J.H. & Kang, H.S. 2015. The relationship between functional physical fitness and mild cognitive impairment in older adults. *Korean Journal of Sports Medicine* 33(2): 102-109.

Jang, J.Y. & Kim, J.H. 2015. Association between handgrip strength and cognitive impairment in elderly Koreans: a population-based cross-sectional study. *Journal of Physical Therapy Science* 27(12): 3911-3915.

Jones, C.J. & Rikli, R.E. 2002. Measuring functional fitness of older adults. *The Journal of Active Aging* 24-30.

Lee, S.H., Han, J.H., Jin, Y.Y., Lee, I.H., Hong, H.R. & Kang, H.S. 2016. Poor physical fitness is independently associated with mild cognitive impairment in elderly Koreans. *Biology of Sport* 33(1): 57-62.

Lin, P.S., Hsieh, C.C., Cheng, H.S., Tseng, T.J. & Su, S.C. 2016. Association between physical fitness and successful aging in Taiwanese older adults. *PLoS ONE* 11(3): e0150389.

Peterson, R. C., Caracciolo, B., Brayne, C., Gauthier, S., Jelic, V. & Fratiglioni, L. 2014. Mild cognitive impairment: a concept in evolution. *Journal of Internal Medicine* 275(3): 214-228.

Reuben, D.B., Seeman, T.E., Keeler, E., Hayes, R.P., Bowman, L., Sewall, A., Hirsch, S.H., Wallace, R.B. & Guralnik, J.M. 2004. Refining the categorization of physical functional status: the added value of combining self-reported and performance-based measures. The Journal of Gerontology. Series A, *Biological Sciences and Medical Sciences* 59(10): 1056-1061.

Rowe, J.W. & Kahn, R.L. 1987. Human aging: usual and successful. *Science* 237 (4811): 143-149.

Sattler, C., Erickson, K.I., Toro, P. & Schröder, J.J. 2011. Physical fitness as a protective factor for cognitive impairment in a prospective population-based study in Germany. *Alzheimers Disease* 26(4): 709-718.

Shahar, S., Omar, A., Vanoh, D., Hamid, T.A., Mukari, S.Z.M.S., Che Din, N., Rajab, N.F., Mohammed, Z., Ibrahim, R., Loo, W.H., Meramat, A., Kamaruddin, M.Z.A., Bagat, M.F. & Razali, R. 2015. Approaches in methodology for population-based longitudinal study on neuroprotective model for healthy longevity (TUA) among Malaysian older adults. Aging Clinical and Experimental Research 1-16 10.1007/s40520-015-0511-4 [3 March 2016].

Studenski, S., Perera, S., Patel, K., Rosano, C., Faulkner, K., Inzitari, M., Brach, J., Chandler, J., Cawthon, P., Connor, E. B., Nevitt, M., Visser, M., Kritchevsky, S., Badinelli, S., Harris, T., Newman, A. B., Cauley, J., Ferrucci, L. & Guralnik, J. 2011. Gait speed and survival in older adults. *JAMA* 305(1): 50- 58.

Taekema, D.G., Gussekloo, J., Maier, A.B., Westendorp, R.G.J. & de Craen, A.J.M. 2010. Handgrip strength as a predictor of functional psychological and social health. A prospective population-based study among the oldest old. *Age and Ageing* 39(3): 331-337.

Tomey, K.M. & Sowers, M.R. 2009. Assessment of physical functioning: a conceptual model encompassing environmental factors and individual compensation strategies. *Physical Therapy* 89(7): 705-711.

Volkers, K.M. & Scherder, E.J. 2014. Physical performance is associated with working memory in older people with mild to severe cognitive impairment. *Biomedical Research Interventions* 762986.

Won, H.L., Singh, D. K. A., Din, N. C., Badrasawi, M., Manaf, Z. A., Tan, S. T., Tai, C. C. & Shahar, S. 2014. Relationship between physical performance and cognitive performance measures among community-dwelling older adults. *Clinical Epidemiology* 6: 343.

Yeoman, M., Scutt, G. & Faraqgher, K. 2012. Insights into CNS ageing from animal models of senescence. *Nature Reviews Neuroscience* 13: 435-445.

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