การศึกษาความสัมพันธ์ระหว่างระดับการศึกษาและความสามารถในการเดินขณะรบกวนกระบวนการคิดในผู้สูงอายุ
Associations between Education Levels and Gait Performance during the Cognitive Dual Tasking in Older Adults

นิพนธ์ต้นฉบับ

Original Article

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วารสารไทยเภสัชศาสตร์และวิทยาการสุขภาพ2566;18(3):220-227.

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บทคัดย่อ

วัตถุประสงค์: เพื่อศึกษาถึงผลกระทบของระดับการศึกษาต่อความสามารถในการเดินและต่อกระบวนการคิดที่เกี่ยวกับความจำทำงานในการทำกิจกรรม 2 อย่างพร้อมกันในผู้สูงอายุ **วิธีการศึกษา:** ผู้สูงอายุกลุ่มที่มีระดับการศึกษาต่ำ จำนวน 20 คน และระดับการศึกษาสูง จำนวน 20 คน เข้าร่วมการศึกษานี้ โดยทั้งสองกลุ่มมีอายุเฉลี่ยใกล้เคียงกัน (อายุเฉลี่ย 68.25 ± 3.46 ปี ในกลุ่มระดับการศึกษาต่ำ และอายุเฉลี่ย 67.85 ± 5.51ปี ในกลุ่มระดับการศึกษาสูง การประเมินความสามารถในการเดินจะประเมินขณะเดินเป็นระยะทาง 10 เมตร และประเมินขณะเดินระยะทาง 10 เมตรร่วมกับการทำกิจกรรมทางความคิด กิจกรรมทางความคิด ประกอบด้วยกิจกรรมลบเลขทีละ 3 กิจกรรมบอกตัวเลขตามที่ได้ยิน และกิจกรรมบอกชื่อคำที่ขึ้นต้นด้วยตัวอักษรที่กำหนด โดยจะมีการสุ่มลำดับของกิจกรรมทางความคิดขณะเดิน **ผลการศึกษา:** ระดับการศึกษามีผลอย่างมีนัยสำคัญต่อความเร็วในการเดิน ($F(1,152) = 13.66$, $p < 0.001$) ช่วงเวลาในการก้าว ($F(1,152) = 11.53$, $p < 0.01$) ระยะก้าวขา ($F(1,152) = 15.81$, $p < 0.001$) และจำนวนก้าวต่อนาที ($F(1,152) = 14.57$, $p < 0.01$) อย่างไรก็ตามระดับการศึกษาไม่มีผลต่อความแปรปรวนในการเดิน และผลของการทำกิจกรรมสองอย่างพร้อมกันด้านกระบวนการคิด **สรุป** ระดับการศึกษามีผลต่อการเดินในการตรวจประเมินความสามารถในการทรงตัวขณะเดินด้วยวิธีรบกวนกระบวนการคิดและการเคลื่อนไหวในผู้สูงอายุ โดยในผู้มีระดับการศึกษาสูงเดินได้เร็วกว่า อย่างไรก็ตามระดับการศึกษาไม่มีผลต่อความแปรปรวนในการเดินและผลของการทำกิจกรรมสองอย่างพร้อมกันในกระบวนการคิดที่เกี่ยวข้องกับกิจกรรมทางความคิดความจำทำงาน

คำสำคัญ: กระบวนการคิด, การรบกวนกระบวนการคิด, ระดับการศึกษา, การเดิน

Abstract

Objective: To examine whether there are education differences in dual-task performances with working memory tasks in older adults. **Methods:** Twenty older adults with a low level of education and 20 older adults with a high level of education participated in the present study. Both groups have a similar age range (low level of education aged 68.25 ± 3.46, high level of education aged 67.85 ± 5.51). Gait was assessed under single task (10-meter walk without a cognitive task) and dual-task (walk with a cognitive task). Three cognitive tasks that were simultaneously performed during walk were subtraction, auditory working memory, and phonologic fluency that randomized in order. **Results:** Main effects of education were found for gait speed ($F(1,152) = 13.66$, $p < 0.001$), stride time ($F(1,152) = 11.53$, $p < 0.01$), stride length ($F(1,152) = 15.81$, $p < 0.001$), and cadence ($F(1,152) = 14.57$, $p < 0.01$). Education levels had no significant main effects on gait variability and cognitive dual-task effect (DTE). **Conclusion:** Education levels significantly affected gait performances in older adults. The older adults with a high education level demonstrated better performances during walking simultaneously with cognitive tasks. However, no effects of education were found on gait variability and cognitive DTE.

Keywords: cognitive, dual-task interference, education level, gait

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Introduction

Aging population is growing rapidly in Thailand. The high level of fertility rates in the early 20th century as well as substantially improved longevity rates account for the steady increase in the number of older persons.[1] Most Thai older people live in the rural areas with under 30% living in the urban counterparts. While 16% have never attended school, most of the elderly have some formal education. However, only 10% have attended secondary school or higher.[1] Higher education was found to be significantly associated with better aging. For instance, Vicerra and Pothisiri[2] reported that education levels were associated with variations in the speed of cognitive aging, in which people with higher levels of education mentally process tasks more efficiently through life, resulting in delayed cognitive aging and cognitive impairment in older people in Thailand. Education is related to neuropsychological performances such as orientation, attention, memory, language, visuo-perceptual abilities, motor skills, and executive function.[3,4] A previous study reported that age and education had an impact on working memory, a brain system that underlies the temporary storage and manipulation of information for such complex cognitive tasks as language comprehension, learning, and reasoning.[5] While age has a negative impact on working memory, education has a positive association with working memory.[6] Pliatsikas et al examined the working memory using a digit n-back task in terms of the influence of age, load (1-back vs. 2-back), and the effects of both sex and education.[6] Their results suggested that higher load led to greater difficulties specifically in older adults when adjusted for age, sex, education, and their interaction. In addition, they reported that education had a positive linear association with working memory abilities where the older adults with higher education performed better than those with lower education in working memory tests.[6]

Executive function refers to a variety of cognitive process that integrates the information from the anterior and posterior brain regions to modulate and produce behavior, and extend to sequences of logical reasoning.[7,8] It is often related to the relevant information which is thought to be maintained in either temporary or long-term storage.[5,9] Declines in executive function, as seen from the attention, psychomotor processing, problem-solving, and awareness of self and surroundings, influence postural control, gait, and falls.[10] In most cases, decrements in executive function have an impact on postural control and gait performance under conditions where the individual also performs an accompanying task of varying cognitive load (i.e., dual-task).[10] Measurement of executive function and its involvement in postural control provides essential information on the prediction of falls.[11] Dual-task test has been used to assess the cognitive-motor interference (CMI) while walking [12], resulting in alteration of spatio-temporal gait parameters such as decreased speed, decreased cadence, decreased stride length, increased stride time, and increased stride time variability in the various population.[13] Such impaired dual-task performance has been associated with an increased risk of falls in the elderly.[14]

In dual-task paradigm, education is an important factor influencing CMI specifically on the accuracy of cognitive performance.[15] Higher education level together with more complex occupational experience are related to better performance on cognitive tests.[16,17] The meta-analysis study gathered the studies that examined the relationship of education level with cognition in relation to cognitive screening measures, memory, working memory, executive function, visuospatial ability, and language. This meta-analysis indicated the significant relationship of education with all the cognitive domains, through small to medium estimated effect sizes.[16]

The cognitive tasks used in dual-task paradigm differed in types and its complexity.[13] The cognitive tasks commonly used in the dual-task paradigm including subtraction, verbal fluency task, and auditory working memory task, seemed to be related to the working memory. The model of working memory consists of three distinct subcomponents known as: 1) the central executive, which is assumed to be an attentional-controlling system, 2) the visuo-spatial sketch pad, which manipulates visual images, and 3) the phonological loop, which stores and rehearses speech-based information and is necessary for the acquisition of both native and second-language vocabulary.[5] The subtraction task is closely linked to the visuo-spatial sketchpad in a subsystem-specific manner of working memory.[18] The verbal fluency tasks require individuals to spontaneously generate works in response to a specific letter cue (i.e., generate words that begin with letter) or category cue (i.e., general animal names).

The phonological loop plays an important role in the letter fluency task, while the visuo-spatial sketchpad supports category fluency performance.[19] The working memory tasks involve the executive attention-control mechanism which seems to be mediated by portion of prefrontal cortex.[20]

Although previous studies addressed the effect of education on cognitive tests, the effect of education on gait performance and its interaction with the nature of cognitive tasks related to working memory during the dual-task test is still unclear. This information can be used for planning specific rehabilitation program for fall prevention in older adults with different education levels who are still active in the community. Therefore, the present study employed a dual-task paradigm with three different cognitive tasks including 1) subtraction, 2) auditory working memory, and 3) phonologic fluency in the elderly with different levels of education. We hypothesized that gait performances should be affected by the level of education. We predicted that the level of education impacts on gait performances during dual-task performances in such a way that gait speed and other gait variables should differ between groups of participants with low and high education.

Methods

Participants

Forty older persons were recruited from the community in the rural areas based on the following inclusion criteria: age 60-80 years, medically stable, and able to walk independently for at least 10 m. The participants were excluded if they had 1) neurological disorders that sufficiently disturb balance, 2) hearing loss, 3) severe visual impairment, 4) orthopaedic conditions or pain affecting natural gait, and 5) comprehension problems, defined as having a Mini-Mental State Examination (MMSE) Thai version score of less than 18 for individuals who completed elementary education, or less than 23 for individuals who have completed levels of higher than primary education.[21] The participants were then classified into two groups based on education level as Low education group (completed primary education or sixth grade) and as High education group (completed higher than sixth grade). Ethical approval was granted by the Mae Fah Luang University Ethics Committee on Human Research. All participants signed a written informed consents prior to participating in the study.

The sample size calculation for the two-way analyses of variance (ANOVA) was carried out using G*power version 3.1.9.7. The minimum of subjects required in the study was 41 persons, based on the estimated values of error probability (α) at 0.05, power (β) at 0.7, and the effect size specification of 0.4.

Measurement tools

Baseline information including age, gender, and education were collected from all participants using the questionnaires. The verbal responses to the cognitive tasks were recorded using the digital recorders. For assessing gait performance, the APDM's Mobility LabTM (APDM Inc.) was used to collect and store data. A gyroscope (±400°/s range) and accelerometer (±5 g range) were used to capture the angular movement and the acceleration at a sampling rate of 200 Hz; gait cycles and related events were detected and estimated. Four portable initial sensors were placed on the participants at sternum, 5th lumbar vertebrae, and left and right ankles. The following four quantitative gait variables were assessed: gait speed (m/s), cadence (steps/min), stride time (s), and stride length (m). Responses to cognitive tasks were recorded using digital recorder. Two raters evaluated the responses from the participants and any repetition was scored once.

Tasks and Procedures

The performance of three main tasks; cognitive task when seated (cognitive-single), 10-meter walk without cognitive task (walk-single), and 10-meter walk with cognitive task (walk-dual) were examined. For cognitive-single, the participants received standardized verbal instructions regarding the cognitive task procedures and were allowed to practice while sitting on a chair. The contents of cognitive task used during practice were not similar to those performed during walk-dual (e.g., different number, different letters) in order to avoid the learning effects. After practice session, the participants performed the cognitive tasks when seated for 60 seconds and the number of correct responses was collected by using a tape recorder. Then, the participants were asked to perform 10-meter walk with and without cognitive task. The cognitive tasks based on previous study were included: 1) subtraction by 3, 2) auditory working memory, 3) phonologic fluency (Table 1).[22]

Table 1 Types of cognitive task and their testing procedures.

No.	Task condition	Instruction
1	Subtraction by 3	Reciting out loud serial subtraction of 3, starting with a random 3 digits number
2	Auditory working memory	Recalling a series of random number
3	Phonologic fluency	Recalling words with a specific letter that was given at the beginning of the test

The order of cognitive tasks was randomly assigned. For the walk-dual, each condition of the task was performed once to avoid the learning effects, and the participants were allowed to rest at the end of each task for 2 minutes before performing the next task to prevent mental fatigue. Figure 1 demonstrates the flow chart of task procedures.

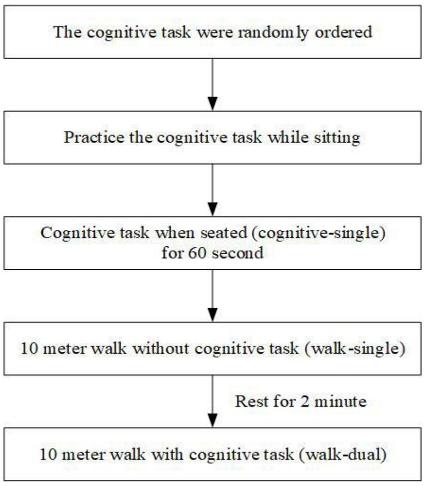

Figure 1 Flow chart of task procedures.

Data analyses

Gait performances

Gait speed, stride time, stride length, and cadence were calculated by using APDM's Mobility Lab software. Stride-to-stride variability, as measured by the coefficient of variation (CV), was measured to indicate the reproducibility of the limb-coordination movements from one stride to the next during walking.[23] Variability in stride time and stride length was quantified by CV (CV = [standard deviation/mean) x 100].[23]

Cognitive performances

The correct response rate (CRR) and the cognitive dual-task effect (DTE) were used to determine cognitive performance. The CRR calculated as: CRR = number of correct responses divided by time, where the "CRR" represents the total correct words generated during the trials and "time" is the time (in seconds) taken to complete task.[24] The DTE was used to determine the influence of addition of cognitive task. As a relative measure of change, the cognitive DTE was calculated for each cognitive task. The decrement cognitive performance under dual-task conditions (cognitive costs) is presented in negative value, while the improvement cognitive performance under dual-task condition is presented in positive values (cognitive benefits).[25] These cognitive DTE was calculated as [25]

$$\text{DTE} = \frac{(\text{CRR dual task} - \text{CRR single task}) \times 100}{\text{CRR single task} \times 100}$$

All statistical analyses were conducted using SPSS statistics software. An assessment of the normality of data was determined by using Shapiro-Wilk test. An independent t-test was used for comparing the age and gait speed between low and high levels of education. Gait parameters and gait variation were analyzed by using two-way (Task conditions (4) x Education group (2)) analyses of variance (ANOVA) to assess the main effect of education group and task condition and also their interactions. The level of significance was set at 0.05. The statistical analyses were conducted using SPSS statistics software. The Bonferroni test was used for post-hoc analyses.

Results

From 40 participants, 20 persons were classified into the low level of education group and 20 were classified into the high level of education group. The participants in both groups were similar in age. Demographic characteristics are presented in Table 2.

Main effects of education were found for gait speed ($F(1,152) = 13.66$, $p < 0.001$), stride time ($F(1,152) = 11.53$, $p < 0.01$), stride length ($F(1,152) = 15.81$, $p < 0.001$), and cadence ($F(1,152) = 14.57$, $p < 0.001$). High education group showed greater speed, greater stride length, greater cadence, and lower stride time than low education group. Main effect of task conditions was also found for gait speed ($F(3,152) = 19.18$, $p < 0.001$), stride time ($F(3,152) = 11.53$, $p < 0.001$), stride length ($F(3,152) = 14.16$, $p < 0.001$), and cadence ($F(3,152) = 14.57$, $p < 0.001$).

Table 2 Demographic characteristic of participants

Demographic variables	Low education (N = 20)	High education (N =20)	P-value
Age (years)[a]	68.25 ± 3.46	67.85 ± 5.51	0.78
Gender (male/female)[b]	8/12	12/8	0.17
Speed (m/s)[a]	0.88 ± 0.15	0.92 ± 0.15	0.65
MMSE score (Thai version)[a]	24.75 ± 2.81	27.60 ± 2.72	
Education level[b]			
1. Primary level	20	-	
2. Secondary level	-	8	
3. High level	-	12	

[a] mean ± SD. [b] number

The post-hoc analysis revealed a statistical difference in these gait parameters between single task and dual-task with all cognitive task conditions. No statistical differences among these three cognitive tasks were indicated. No significant interaction of Education*Task condition in gait performances was found. Figure 2 shows the representative task conditions and gait characteristics (speed, stride time, stride length, and cadence).

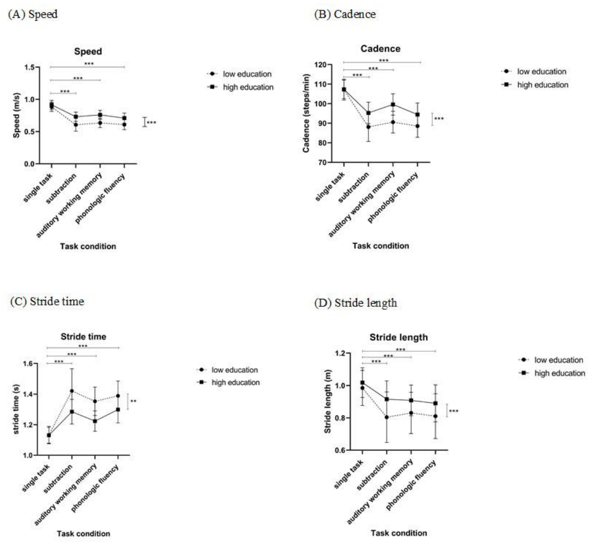

Figure 2 Gait parameters (with 95%CI) of (A) Speed, (B) Cadence, (C) Stride time, (D) Stride length, comparing between the older adults with low level of education and high level of education.
**depicts a significant difference at p < 0.01. ***depicts a significant difference at p <0.001.

In contrast, no main effect of education was found for gait variability (CV stride time: F(1, 152) = 2.30, p = 0.13; CV stride length: F(1, 152) = 0.88, p = 0.35). The main effect of task condition was found only for gait variability (CV stride time: F(3, 152) = 8.50, p < 0.001; CV stride length: F(3, 152) = 7.17, p < 0.001). The post-hoc analysis revealed the statistical difference for both gait variabilities between single task and dual-task with all cognitive tasks. Also, there were statistical differences of CV stride time between subtraction task and auditory working memory task, auditory working memory and phonologic fluency task, but not between subtraction and verbal fluency task. For the CV stride length, there was no statistical difference between the cognitive tasks. The interaction of Education*Task condition was not found for CV stride time F(3, 152) = 0.962, p = 0.41) and CV stride length F(3, 152) = 1.12, p = 0.34). Figure 3 shows the representative task conditions and gait variation (CV of stride time and CV of stride length).

For the cognitive DTE, no main effect of education and task conditions was found (F (1, 114) = 0.13, p = 0.72 and F (2, 114) = 0.98, p = 0.38, respectively). No statistical difference in cognitive DTE among subtraction, working memory, and phonologic fluency task was found. Also, there was no interactive effect of Education*Task condition (F (2, 114) = 0.10), p = 0.91). Figure 4 shows the representative task conditions and cognitive DTE.

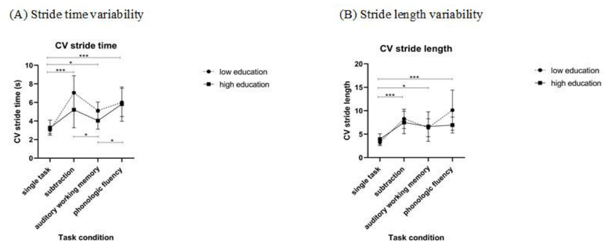

Figure 3 Gait variability (with 95%CI) of (A) Stride time variability and (B) Stride length variability between the older adults with low level of education and high level of education. *depicts a significant difference at p < 0.05.
***depicts a significant difference at p <0.001.

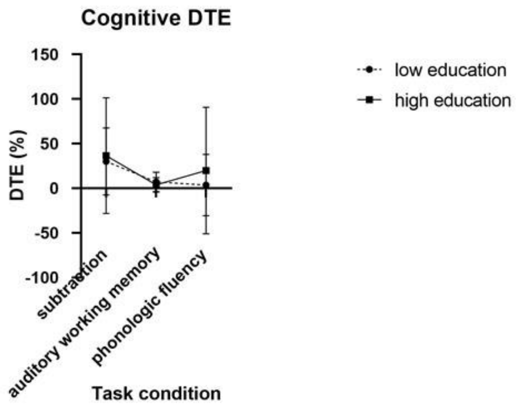

Figure 4 Cognitive DTE (with 95%CI) between the older adults with low level of education and high level of education.

Discussions and Conclusion

Education attainment has been linked to the socio-demographic and economic status. In 2000, 80 to 90 percent of older adults in most developing countries have low levels of completed education i.e., completed primary education or lower.[26] The results of our study support our hypotheses, and provide evidence regarding the impact of education levels on dual-task performances in the older adults. Education is one of the important factors that the clinician should concern that it might be effect on the dual-task performances for assessing risk of falls in the older adults.

Our study showed the effect of education levels on all gait performances, but not on gait variability. Older adults with lower education demonstrated decrease in gait performance, i.e., gait speed, stride length, and cadence, during cognitive dual task than those with higher education. Gait speed is one of the useful outcome measurements that can reflect physical function.[27] Study by Holtzer et al.[28] revealed that gait speed is associated with the cognitive function and its relationship varies as a function of task condition. Our findings were in agreements with previous study that reported the effects of education on dual-task performances. Study by Gomes et al. [29] reported the increased time to perform TUG-dual in older adults with lower education level. The possible explanation could be due to the relationship between education and cognitive function. Education is associated with global cognition, episodic memory, semantic memory, and also complex mental activity and cognitive reserve.[30,31] People with lower number of years of formal education tend to perform more poorly on tasks involving executive function.[32] In addition, lower levels of education are strongly related to greater risk of cognitive decline.[33] Executive functions are associated with gait performances during the dual-task condition. [34] Decrease in gait performances are also found in the elderly with poor executive function.[35,36]

In this study, three working memory tasks were selected to examine the relationship between the education level and gait performance in dual task. We demonstrated that all these tasks had similar impact on the gait performance during dual task, possibly due to our participants perceived equal difficulty of all cognitive tasks.

Besides gait parameters, the degree of gait variability is closely related to fall risk than average value of walking parameters (e.g. average gait speed, average stride length, and average stride time).[37, 38] Gait variability may reflect the inconsistency in the central neuromuscular control system's ability to regulate gait and maintain a steady walking pattern, so measures of gait variability would be associated with instability and fall risk.[39] For the gait variability, we found that adding cognitive task led to increase in gait variability. Also, the increase in gait variation depends on the tasks. The subtraction task and phonologic fluency task were higher increased in gait variation than auditory working memory task. The possible explanation may be due to the higher neural activities of subtraction and phonologic fluency task which potentially derived the neural mechanism of posture and cognitive processing. The subtraction task triggered neural activity in occipito-temporal visual regions, parietal areas, frontal, prefrontal regions, bilateral insula, and right cerebellum.[40] The prefrontal cortex may be essential for balance control.[41, 42] Also, the frontal-parietal network involves in postural control and working memory process.[43]

The phonologic fluency activated neural networks in the left inferior frontal cortex and the supplementary motor areas. [44,45] The supplement motor area plays the important role in postural control and anticipatory postural adjustment of human gait initiation.[46] While, the working memory task involves an executive attention control mechanism which mediated by portions of the prefrontal cortex.[47] However, study by Beauchet et al.[48] found that gait variability increased significantly when walked with subtraction task but not for category fluency task (enumerating animal name) in the elderly. In the same line, this study reported significant reduction in the number of responses during subtraction task than category fluency task, which could lead to greater stride time variability during subtraction condition.

In the current study, no effect of education level and tasks was observed on the cognitive DTE. The results of our study showed that education affects motor performance but not cognitive costs. Our findings are consistent with a previous report demonstrating that education attainment and adding cognitive task led to decrease in TUG performance, but the rate of correct response was not affected by education levels.[49] It was plausible that during walk whilst concurrently performing cognitive task, the task appeared to take priority over maintenance of walking speed in the elderly. The well-known theories such as capacity sharing theory and bottle neck theory have been developed to explain the difficulties in simultaneous performance of dual-task.[50] The capacity sharing theory proposed that the processing capacity was shared among task, therefore there will be less capacity for each individual task when performing more than one task at any given time.[50] As the attention resources are limited in capacity when performing two attention demanding tasks, it will cause deterioration of at least one of the tasks.[51] The bottleneck theory proposed that when two tasks were needed to process at the same time, one or more tasks will be delayed or impaired.[50] Therefore, this indicates that the elderly spontaneously favors one activity over the other.

The findings in this study that education level was associated with gait performances in the older adults could be applied in the clinical practice for assessing the dual-tasking in those with different education levels. Clinicians or researchers should take into account the education level of the individual when performing the dual-task assessment. A possible limitation of this study was that the heterogeneity of our participants. Since the results of this study were obtained from the elderly where most of them live in the rural areas, the generalization of the results is limited. Next, the leisure activities and occupation were also associated with cognitive function[52], but such information was not reported in this study.

In summary, the present findings suggest that education level affect gait performances. Gait speed, stride length, and cadence during dual-task walking were observed to be lower in the older adults with low level of education, as compared to high level of education. This can be applied to the clinical practice as it will enable the clinicians to concern that education might affect the gait performances during dual-task testing for prediction of falls in the older adults.

Ethics Statement

The present study was reviewed and approved by Mae Fah Luang University Ethics Committee on Human Research (MFU EC). The participants provided their written informed consents to participant in this study.

Author Contributions

AP conceived and designed the project, the function procurement, and collection of the data. RB helped in the preparation of the final draft of manuscript. SK and PK helped in the instrumentation and data analysis.

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