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Weak hip flexor strength predicts progression of functional capacity decline due to locomotor system dysfunction in community-dwelling older adults: A longitudinal cohort study

Running Title

Progression of locomotive dysfunction and physical function

Author names

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31 **ABSTRACT**

32 **Purpose:** It is critical to determine the risk factors for activities of daily living (ADL) disability caused by
33 locomotor dysfunction. However, no longitudinal study has investigated the association between disability due to
34 locomotive dysfunction and multidimensional factors. Therefore, we investigated the relationship between the
35 progression of functional capacity decline due to locomotive dysfunction and multiple physical functions among
36 older adults in a longitudinal study.

37 **Methods:** The participants comprised of 433 community-dwelling older adults. Physical function was assessed at
38 baseline, which included handgrip strength, maximal isometric strength of hip flexion, hip extension, hip
39 abduction, knee extension, toe flexion (index for muscle strength), the 5-time chair–stand test (index for muscle
40 power), the one-legged stance and timed “Up & Go” tests (index for balance function), the 30-s stair test (index
41 for muscle endurance), and range of motion (ROM) (an index of joint condition). Functional capacity decline due
42 to locomotive dysfunction was assessed using the 25-question Geriatric Locomotive Function Scale (GLFS-25)
43 before and after a 12-month period. Based on changes in the GLFS-25 score compared with baseline, the non-
44 decline and decline groups were operationally defined. Logistic regression analyses with the groups as the
45 dependent variable and physical function as independent variables were performed.

46 **Results:** Of the 433 participants, 189 (43.6%) were included in the decline group. Logistic regression analysis
47 revealed hip flexor strength as a primary determinant in the progression of functional capacity decline.

48 **Conclusion:** These results suggest that among physical functions, hip flexor strength influences the progression of
49 disability resulting from locomotive dysfunction in older adults.

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51 **KEYWORDS**

52 Aging; Locomotive dysfunction; Physical function; Muscle strength; Balance function

1. INTRODUCTION

Age-related functional deterioration in locomotive organs, such as bones, joints, and muscles, is one of the major issues that result in disability in performing daily activities. This leads to an increase in the number of older adults requiring nursing care (Nakamura, 2008). Several studies have shown that activities of daily living (ADL) disability caused by locomotive organ disorders are also related to the risk of falls (Akahane et al., 2016; Kimura, 2018). Therefore, prevention of the decline in mobility and muscle function resulting from problems related to the locomotive system is the most important concern for prolonging healthy life expectancy in older adults.

The 25-question Geriatric Locomotive Function Scale (GLFS-25) is a screening tool for the early detection of conditions under which older adults will need nursing care in the near future due to functional deterioration in locomotive organs. The GLFS-25 is a self-administered measurement tool that consists of 25 items regarding pain, ADL, social activities, and mental health (Seichi et al., 2012). Several studies have demonstrated the relationship between disabilities in ADL due to functional deterioration assessed using the GLFS-25 and motor functions, such as skeletal muscle strength and balance function. In fact, balance function and physical performance, such as the one-legged stance test (OLST), timed “Up & Go” (TUG) test, and walking speed, have been identified as predictors of subsequent disability in ADL assessed by the GLFS-25 in older adults (Ikemoto et al., 2016; Kobayashi et al., 2019a; Muramoto et al., 2012, 2013; Nakamura et al., 2015). With regards to skeletal muscle strength, weakness of lower limb muscles, hand grip, and trunk extensor strength are also considered to be major risk factors for ADL disability (Ikemoto et al., 2016; Kobayashi et al., 2019b, 2020; Nakamura et al., 2015).

The frequency of activity limitations is high in walking-related activities (“walking briskly,” “walking a long distance,” and “going up and down stairs) in older adults with a mild level of mobility disability (Akai et al., 2016). In addition, mobility disabilities restrict social activities. It has been pointed out that a decrease in lower extremity function, especially in lower extremity muscle function, is associated with a greater risk for developing mobility dysfunction. Walking speed has been shown to be more closely associated with hip flexion or abduction muscle strength than with knee extension strength in older adults (Inoue et al., 2017; Iwaya et al., 2017). In addition, previous studies concluded that not only a decrease in muscle strength, but also in muscle power and endurance, caused a decline in the ability to perform daily activities (Bohannon, 1997; Guralnik et al., 1995; Kuo et al., 2006; Roshanravan et al., 2017). However, only a few studies have addressed the association between disability in ADL or restriction in social activity due to locomotive dysfunction and various lower limb muscle functions, including the hip muscle.

To develop intervention strategies to prevent a decline in the ability to perform ADL and social activity, it

is necessary to investigate the relationships between functional disabilities due to locomotive organ dysfunction and multiple physical functions, thereby determining the risk factors for the occurrence and progression of functional deterioration due to locomotive dysfunction. However, to the best of our knowledge, no longitudinal study has investigated the association between future functional deterioration due to locomotive dysfunction and multidimensional factors involved in physical function in older adults. Therefore, this longitudinal study aimed to investigate the relationship between progression of functional capacity decline due to locomotive dysfunction assessed using the GLFS-25 and multidimensional factors involved in physical function, such as muscle strength (handgrip, hip flexion, extension, and abduction; knee extension; and toe grip strength), muscle power, muscle endurance, balance function, and range of motion (ROM) of the knee joint among community-dwelling older adults in a longitudinal study.

The purpose of the present study was to determine the risk factors for the progression of functional deterioration due to locomotive dysfunction. We hypothesized that the decline in physical function, especially lower extremity muscle function, was the primary determinant for future functional deterioration.

2. METHODS

2.1. Participants

Data were obtained from the second-visit dataset of the Nagahama Prospective Cohort for Comprehensive Human Bioscience (the Nagahama Study) between 2013 and 2017 ($n = 9,850$), annually carried out in Nagahama City, a rural area of the Shiga Prefecture of Japan. The details of participant recruitment have been described elsewhere (Tabala et al., 2018). Among the 5018 participants aged 60 years or older, 2121 participated in an optional physical examination. Of the 2,121 participants between 2013 and 2017, a follow-up investigation of the 25-question Geriatric Locomotive Function Scale (GLFS-25) after 12 months was conducted only for individuals who participated in the physical examination in 2014 ($n = 520$). We excluded participants with missing data in the follow-up investigation of the GLFS-25 after 12 months ($n = 75$). In addition, the exclusion criteria of this study were as follows: 1) a recent history of orthopedic surgery on the spine and limbs; 2) incomplete measurement of physical function due to physical dysfunction, such as severe musculoskeletal and acute neurological impairments; 3) complaints of pain and fatigue during measurements of physical function; 4) inability to walk or climb a 30-cm stair without assistive devices; and 5) communication problems due to cognitive impairments that affected the measurements. We excluded participants with incomplete measurements

113 due to severe musculoskeletal impairments ($n = 4$), complaints of lower limb pain and fatigue during the
114 measurements ($n = 5$), and lack of physical function data ($n = 3$). Complete data were available for 433 older
115 adults (140 men, 293 women, aged 67.2 ± 5.00 years; mean height, 157.1 ± 8.11 cm; mean body mass, 56.3 ± 9.59
116 kg), all of which were used for the data analysis (Fig. 1). All study procedures were approved by the Ethics
117 Committee of the Kyoto University Graduate School of Medicine (G278) and by the Nagahama Municipal
118 Review Board. The participants were informed about the study procedures before testing and provided written
119 informed consent before participation.

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121 **2.2. Experimental protocol**

122 The baseline physical function was assessed, including handgrip strength, maximal isometric strength of
123 hip flexion, hip extension, hip abduction, knee extension, toe flexion (an index of muscle strength), 5-time chair
124 stand test (an index for muscle power), OLST (an index for balance function), TUG test (an index for mobility and
125 balance function), 30-s stair test (an index for muscle endurance), and the ROM of knee flexion and knee
126 extension (an index of joint condition). Functional deterioration due to locomotive dysfunction was assessed using
127 the GLFS-25 (Seichi et al., 2012) before and after a 12-month period. The participants were classified into two
128 groups (decline group or non-decline group) based on changes in the GLFS-25 score compared with baseline.
129 Logistic regression analyses with the dependent variable as the groups and the independent variables of physical
130 function were performed to determine the association between functional deterioration due to locomotive
131 dysfunction and physical function.

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133 **2.3. Measurement of physical function**

134 Physical function was assessed at baseline, which included handgrip strength, maximal isometric strength
135 of hip flexion, hip extension, hip abduction, knee extension, and toe flexion, the 5-time chair–stand test (5CST),
136 OLST, TUG test, 30-s stair test, and ROM of knee flexion and extension. Physical function was measured by a
137 well-trained examiner for each measurement method.

138 Handgrip strength was measured alternately using a standard digital grip dynamometer (Grip-D; Takei
139 Scientific Instrument Co., Ltd., Niigata, Japan, or YD, TTM, Tokyo, Japan) in a sitting position. The
140 measurements were performed twice for each hand with the elbow extended and the arm position vertical to the
141 ground, and the maximum value of all measurements was used for the analysis (Tabara et al., 2020).

142 Lower-limb muscle strength was determined by measuring the maximal isometric strength of hip flexion,

143 hip extension, hip abduction, knee extension, and toe flexion. All measurement protocols including measurement
144 position and device were based on our previous study (Inoue et al., 2017), which indicated a high degree of
145 reproducibility in measuring muscle strength in a pilot study. A systematic review (Mijnarends et al., 2013) also
146 showed high reliability and validity for measuring lower limb muscle strength using a hand-held dynamometer.
147 Muscle strength in the right leg was measured twice after the pre-measurement trial, and the maximum value of
148 the two measures was used for analysis. Maximal isometric strength was measured using the dynamometer only
149 after the participants were familiarized with maximal isometric contraction by pre-measurement trials. A resting
150 period was provided between the two measurements of strength, taking fatigue into consideration. The muscle
151 strength of hip flexion was measured in a sitting position with the hip flexed at 90° and the knee flexed at 90°
152 using a hand-held dynamometer (HHD) (Hand-held dynamometry Mobie, Sakai Iryou Co., Ltd. Tokyo, Japan).
153 The HHD sensor was applied to the distal side of the anterior surface of the thigh. The muscle strength of hip
154 abduction was measured in the supine position with the hip and knee fully extended and the hip positioned at
155 neutral abduction using the HHD (HHD; Mobie, Sakai Iryou Co., Ltd. Tokyo, Japan). The HHD sensor was
156 applied 5 cm proximal to the lateral malleolus. The muscle strength of the hip extension was measured using a
157 specialized dynamometer (Locomoscan, Alcare Co., Ltd. Tokyo, Japan). The participants were placed in a long
158 sitting position with their hips fixed by a belt to maintain a hip joint position of 70° flexion. A force sensor of the
159 dynamometer was placed in the popliteal region. The participants were asked to press their thighs against the
160 sensor with maximum force. The muscle strength of knee extension was measured using a dynamometer
161 (Musculater, OG Giken Co., Okayama, Japan) with the participants in a sitting position with their hip and knee
162 flexed at 90°. The dynamometer sensor was placed at 25 cm distal to the knee joint. The hip flexion, hip
163 extension, hip abduction, and knee extension strength values were converted into torque (Nm) by multiplying the
164 values by lever arm length (m) and then normalizing the torque to their weight (Nm/kg). Toe flexion strength was
165 measured using a specialized device (Takei Kiki Co., Niigata, Japan) with the participants in a sitting position
166 with their hip and knee flexed at 90° and ankle joint in a neutral position. The ankle joint was attached to the
167 device by a belt, and the interphalangeal joints of the toes were aligned to cross the toe grip bar of the sensor.

168 The 5CST was used to represent muscle power. The time required to stand five times from a standard chair
169 without using the upper extremities was measured once according to a previously described method (Guralnik et
170 al., 1994). The participants were asked to rise to a full standing position and then return to the seated position as
171 quickly as possible. Timing began when the examiner said "Go" and stopped when the participants' buttocks
172 touched the chair on the fifth repetition. The chairs used were all 42 cm in height.

173 OLST with eyes open was used to determine the balance function. OLST on either leg, as determined by
174 the individual, was measured using a digital stopwatch for a maximum time of 60 seconds, based on previous
175 studies examining the association between the GLFS-25 score and OLST (Muramoto et al, 2013, Nakamura et al,
176 2015). The trial was performed twice, and the maximum value was used for analysis. The TUG test was developed
177 as a test of mobility in frail older people (Podsiadlo & Richardson, 1991) and consists of multidimensional
178 components including getting up from a chair, walking, turning, returning to the chair, and sitting down. The TUG
179 test performed at a maximum pace is a useful measurement for identifying older adults at risk of falls (Sai et al.,
180 2010, Shumway-Cook et al.,2000). For the TUG test, the participant was instructed to stand up from a sitting
181 position from an armless chair, walk a distance of 3 m, turn, walk back to the chair, and sit down at a maximum
182 pace (Sai et al., 2010, Shumway-Cook et al.,2000). Participants performed the TUG test once but were allowed to
183 repeat the test if they did not complete the first test correctly. The time was measured from the start until the
184 participant sat down on the chair.

185 The 30-s stair test was used as an index of muscle endurance. The 30-s stair test measured the total number
186 of steps within 30 s using a 30 cm height step (Araki et al., 2016). The starting position was the position at which
187 the right foot was placed on the step. The subject was asked to step up their left foot onto the step and then return
188 to the starting position as rapidly as possible. The test was performed once at maximum speed.

189 The ROM of knee flexion and extension in the right leg was measured using a goniometer. The ROM of
190 knee flexion was measured in the supine position with the hip flexed, while the ROM of knee extension was
191 measured in the supine position with the hip extended. The knee was passively flexed or extended by the examiner
192 to the maximum angle at which there was no discomfort or pain.

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194 ***2.4. Assessment of functional deterioration due to locomotive dysfunction***

195 Functional deterioration due to locomotive dysfunction was assessed using the GLFS-25 before and after
196 12 months. The GLFS-25, whose validity and reliability have been confirmed (Seichi et al., 2012, 2014), is a
197 relatively comprehensive measurement tool. The GLFS-25 is a self-administered measurement tool that consists
198 of 25 items that include four questions regarding pain, 16 questions regarding basic ADL (such as standing,
199 walking indoors, and taking a bath) and instrumental ADL (such as using public transportation and performing
200 housework), three questions regarding social function (such as joining social activities and performing sports
201 activities), and two questions regarding mental health (e.g., feeling anxious and fear of falls) during the last
202 month. Each of the 25 items was scored from 0 (no impairment) to 4 (severe impairment). The maximum score is

203 100 points, and a higher score represents a poor locomotive function.

204 We calculated the change in the GLFS-25 score over a period of 12 months. A large score reflects a
205 worsening of the locomotive dysfunction. According to the change in the GLFS-25 score over a period of 12
206 months, the participants were classified into two groups (decline group or non-decline group). The non-decline
207 and decline groups were operationally defined based on the quartiles of the change in the GLFS-25 score. The
208 upper quartiles of Q1 and Q2 (i.e., a decrease in the GLFS-25 score ≥ 0) were defined as the non-decline group.
209 The lower quartiles of Q4 and Q5 (i.e., an increase in the GLFS-25 score ≥ 2) were defined as the decline group.

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211 **2.5. Covariates**

212 Body height and weight were converted into body mass index (BMI, kg/m²). Depressive symptomatology
213 was evaluated using the 20-item version of the Center for Epidemiological Studies Depression Scale (CES-D;
214 range 0–60 points) (Kohout et al., 1993; Rushton et al., 2002). Higher scores indicated more severe depressive
215 symptoms. We used the Japanese version of the CES-D, which has been previously validated in the Japanese
216 population (Shima et al., 1985).

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218 **2.6. Statistical analysis**

219 All data are presented as the mean $\pm$ SD. Differences in the GLFS-25 scores between baseline and after 12
220 months were examined using the paired *t*-test.

221 Differences between the decline and non-decline groups were examined using the Mann-Whitney test for
222 means and Pearson's Chi-square test for proportions. Logistic regression analyses, with the groups as the
223 dependent variable and age, sex, BMI, CES-D, GLFS-25, total score or each domain score at baseline, and
224 physical function as the independent variables, were performed to determine the association between future
225 decline in functional capacity due to locomotive dysfunction and physical function. To identify the differences in
226 these associations by age, the participants were classified into two subgroups (aged ≤ 65 years vs. > 65 years), and
227 logistic regression analyses were conducted by adjusting for the covariates.

228 The level of statistical significance was set at 5%.

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231 **3. RESULTS**

232 Table 1 presents the baseline characteristics of the participants. The GLFS-25 score at the 12-month

233 follow-up (8.36 ± 10.2) was significantly greater than that at baseline (6.68 ± 8.14). Of the 430 participants, 189
234 (43.6%) were included in the decline group, with an increase in the GLFS-25 score ≥ 2 , and 195 (45.0%) in the
235 non-decline group, with a decrease in the GLFS-25 score ≥ 0 .

236 The GLFS-25 score at baseline in the non-decline group was significantly greater than that in the decline
237 group (decline group: 4.96 ± 6.58 , non-decline group: 9.18 ± 9.41). Conversely, the GLFS-25 score at the 12-
238 month follow-up in the decline group was significantly greater than that in the non-decline group (decline group:
239 13.7 ± 12.2 , non-decline group: 4.23 ± 5.91). In the decline group, GLFS-25 scores for all domains, especially in
240 the basic ADL and pain domains increased after 12 months.

241

242 Table 2 summarizes the differences between the decline and non-decline groups. Hip flexor strength was
243 significantly lower in the decline group than in the non-decline group (decline group; 0.80 ± 0.23 Nm/kg, non-
244 decline group; 0.87 ± 0.23 Nm/kg). There were no significant differences between the two groups in terms of
245 physical function, except for hip flexor strength.

246 In the logistic regression analysis for functional capacity decline due to locomotive dysfunction with age,
247 sex, BMI, and physical function as the independent variables, only hip flexor strength was revealed as a
248 significant and independent determinant (Table 3). Hip flexor strength remained significant after adjustment for
249 CES-D score and GLFS-25 total score at baseline in Model 2 (Table 3). The logistic regression analysis with
250 adjustments for the covariates including each domain of GLFS-25 in Model 3 showed that hip flexion strength, as
251 well as pain and social function scores were significant and independent determinants.

252 In the sub-analysis by age, hip flexor strength was revealed as a significant and independent determinant in
253 participants aged ≤ 65 years, whereas no significant association was observed in participants aged > 65 years
254 (Table 4).

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257 4. DISCUSSION

258 In this longitudinal study, we examined the influence of physical function involving muscle strength
259 (handgrip; hip flexion, extension, and abduction; knee extension; and toe grip strength), muscle power, muscle
260 endurance, balance function, and range of motion (ROM) of the knee joint on the progression of functional
261 capacity decline resulting from locomotive dysfunction during the 12-month follow-up period among community-
262 dwelling older adults. This is the first longitudinal study to show that older adults with weak hip flexor strength

263 are at higher risk of developing ADL disability and restricted social activities related to locomotive organs.

264 It is a well-known fact that problems related to locomotive organs are the main reasons for ADL disability
265 and restrictions on social activities in older adults. Therefore, early detection of a decline in mobility resulting
266 from dysfunction of the locomotive system may be a major potential solution to prevent or delay disability
267 progression among older adults. In the present study, the GLFS-25 score at the 12-month follow-up was
268 significantly greater; that is, progression of disability in performing daily and social activities were observed
269 during the 12-month follow-up period. Furthermore, although the GLFS-25 score at baseline was lower in the
270 decline group than in the non-decline group, progression of disability was observed in the decline group. The
271 results suggest the importance of intervention in an earlier stage of the disability process to prevent future
272 disability, even in high-functional older adults. In addition to our findings, a previous study showed that older
273 adults with the highest mobility performances at baseline were more likely to show a greater decline in walking
274 ability than the other groups during the 1-year follow-up period (Yamada et al, 2012). Further longitudinal
275 research is required as the mechanism of the findings is unclear.

276 Physical impairments have been shown to be related to ADL disability and restricted social activities due
277 to locomotive system dysfunction in cross-sectional studies. However, examination of the association of
278 functional deterioration due to locomotive dysfunction and multiple involvements in physical function in
279 longitudinal survey data is still insufficient. The current longitudinal study indicated that only hip flexor strength
280 was a primary predictor of the risk of disability progression caused by locomotive system dysfunction at the 12-
281 month follow-up in all Models of logistic regression analysis. Our results suggest the usefulness of assessing hip
282 flexor strength not only for early detection of the risk of future functional dependence for ADL or restriction on
283 social activities but also for the prevention of the strategies of disability progression in older individuals. Several
284 studies have shown that physical performance and health characteristics are more strongly associated with lower
285 extremity muscle strength than upper extremity muscle strength (Bijlsma et al., 2014; Yeung et al., 2018). Our
286 results indicated that among lower extremity muscle strength (hip flexion, extension, and abduction, knee
287 extension, and toe grip strength), a decline in hip flexor strength was most strongly associated with the risk of
288 progression of ADL disability and restricted social activities resulting from locomotive system dysfunction. One
289 plausible explanation for our finding is that age-related muscle atrophy is greater for the psoas major muscles
290 among lower limb muscles (Ikezoe et al., 2011; Takahashi et al., 2006), thereby decreasing hip flexor strength and
291 accelerating the process of mobility limitation. Another possible explanation is that the psoas major muscle is
292 closely related to locomotor capacity, such as walking fast, stair climbing, and running, which causes a functional

293 decline in the early stages of aging (Andersson et al., 1997; Kim et al., 2000, 2010; Masuda et al., 2002).
294 Considering these findings, hip flexor strength may contribute to maintaining locomotor capacity and slowing
295 down the process of deterioration of disability caused by locomotive system dysfunction among older adults. In
296 addition, the results of the logistic regression analysis adjusted for the covariates, including each domain of
297 GLFS-25 at baseline, indicated that the pain and social function scores were also significant predictors of
298 functional deterioration due to locomotive dysfunction, suggesting that pain and social function, among the
299 domains of the GLFS-25, have a strong influence on the progression of disability resulting from locomotive
300 dysfunction.

301 Our results showed that age and sex were not risk factors for the progression of disability. It is well known
302 that physical function decreases with aging, and skeletal muscle strength is lower in women than in men. Cross-
303 sectional examinations also showed that age and gender differences were observed in the GLFS-25 score
304 (Kobayashi et al., 2019b; Yoshimura et al., 2015). Our findings suggest that the progression of functional capacity
305 decline due to locomotive dysfunction may not be influenced by age and sex. In addition, the results of the sub-
306 analysis by age showed that hip flexor strength was a significant predictor of functional deterioration due to
307 locomotive dysfunction in participants aged ≤ 65 years but not in participants aged > 65 years. The identification
308 of factors related to ADL disability caused by locomotive dysfunction is required to develop early intervention
309 programs and prevent disability. Therefore, our findings suggest the usefulness of hip flexor strength for early
310 intervention programs to prevent disability progression, especially in the relatively young-old age group, such as
311 those aged 60–65 years.

312 The results of the sub-analysis in participants aged ≤ 65 years in Model 2 indicated that hip flexor strength,
313 as well as TUG were significant predictors of functional deterioration due to locomotive dysfunction. Cross-
314 sectional studies have also shown that TUG scores are closely related to basic and instrumental ADL limitations
315 (Kim et al., 2010; Shimada et al., 2010) and GLFS-25 scores (Muramoto et al, 2013). To perform the TUG test,
316 various mobility functions, including getting up from a chair, walking, turning, returning to the seat, and sitting
317 down, are required. The items of the GLFS-25 also include a decrease in mobility, such as standing and walking.
318 Thus, the results of our longitudinal study suggest that functional deterioration due to locomotive dysfunction may
319 be strongly influenced by mobility, which is measured by the TUG test, especially in the relatively young-old age
320 group, including the participants aged 60–65 years.

321 Interestingly, our longitudinal study showed that the OLST score was not a risk factor for the progression
322 of disability due to locomotive organ dysfunction during the 12-month observation period. Poor balance is a well-

known risk factor for a higher probability of ADL disability. The optimal cut-off time for the OLST for early identification of mobility disability has been suggested to be 19 s for individuals aged ≤ 70 years (Seichi et al., 2014). Compared to the cut-off values in previous studies, the participants in the present study had better balance function at baseline. Their relatively high physical functioning may explain why there was no relationship between balance function and the progression of disability in the near future.

This study has several limitations. First, as follow-up data on physical function were not obtained in the present study, we could not conclude about the predictability of future disability caused by locomotive system dysfunction for future loss of physical function. However, a decline in hip flexor strength seems to be a useful predictor of a higher risk of future ADL disability in community-dwelling older adults. Second, in the present study, the decline group was operationally defined based on the quartiles of the change in the GLFS-25 score (i.e., an increase in the GLFS-25 score ≥ 2), as meaningful changes in the GLFS-25 score, such as the minimal detectable change (MDC), were not identified. However, the definition of progression of functional decline based on MDC could have helped to make our findings more clinically meaningful. Third, since the participants of the present study were highly functional community-dwelling older adults who were able to complete the physical function and GLFS-25 measurements, it should be noted that the findings of this study are not generalizable to all older adults. Finally, this longitudinal study was the short follow-up period of 12 months. In addition, we did not examine the details of the medication, medical comorbidities, physical activity level, history of falls, cognitive function, and social status. Additional longitudinal studies with longer duration, including multidimensional factors, are necessary to clarify the association between future ADL disability due to locomotive dysfunction and future loss of physical function in older adults.

5. CONCLUSION

We investigated the relationship between future functional capacity decline due to locomotive dysfunction and physical function among community-dwelling older adults in a longitudinal study. Our results showed that hip flexor muscle strength was a primary determinant of future functional deterioration due to locomotive dysfunction, especially in the relatively young-old age group, including participants aged 60–65 years. These results suggest that among physical functions, hip flexor strength influences the progression of ADL disability and restricted social activities resulting from dysfunction of the locomotive system. This information will be useful in identifying the risk of future disability in addressing the issue of nursing care.

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CONFLICT OF INTEREST

The authors have nothing to disclose.

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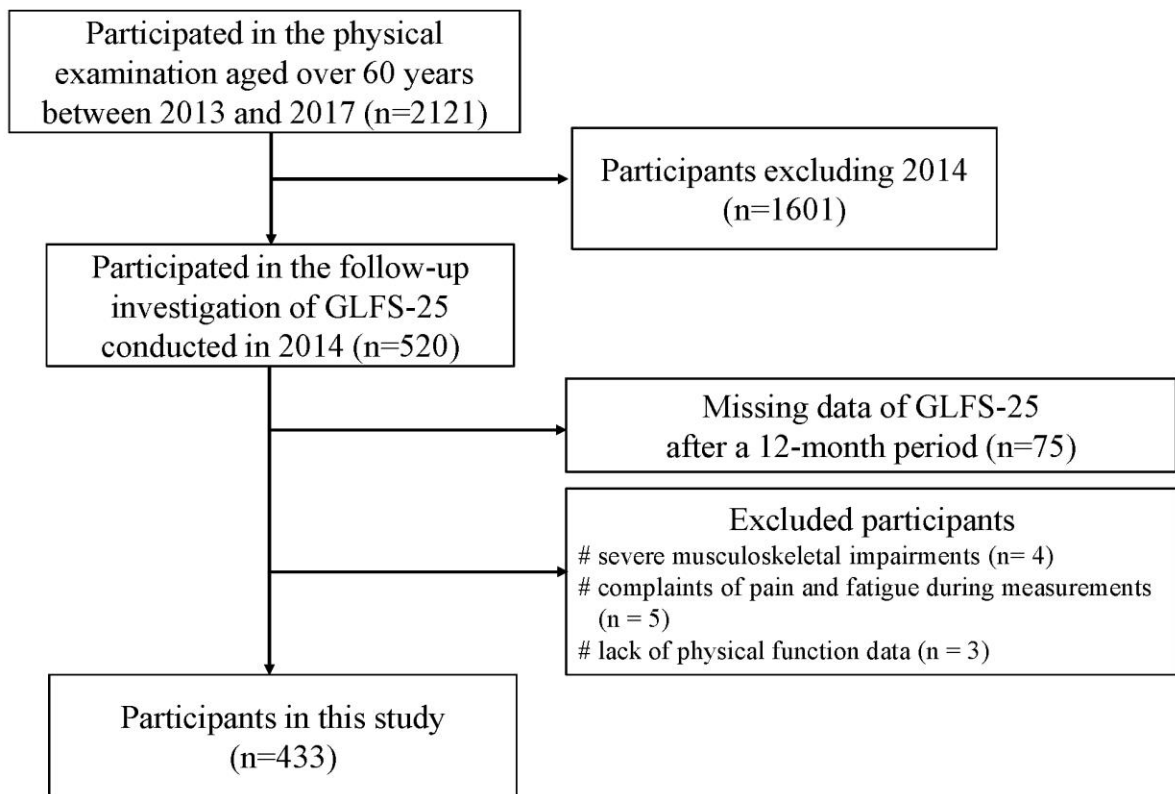


Figure 1. Flow chart for the selection of study participants

516 **Table 1. Characteristics of participants at baseline**

	Total (n = 433)
Age (year)	67.2±5.00
Sex; Female, n (%)	293 (67.7%)
Height(cm)	157.1±8.11
Mass (kg)	56.3±9.59
BMI (kg/cm ²)	22.7±3.06
CES-D (score)	12.1±7.09
GLFS-25 score (score)	6.68±8.14
Handgrip strength (kg)	28.6±8.21
Hip flexion strength (Nm/kg)	0.83±0.24
Hip extension strength (Nm/kg)	1.62±1.53
Hip abduction strength (Nm/kg)	0.76±0.20
Knee extension strength (Nm/kg)	2.04±0.70
Toe flexion strength (kg)	14.9±5.47
5CST (sec)	8.23±2.35
OLST (sec)	44.6±19.3
TUG (sec)	6.44±1.16
30-s stair test (time)	26.0±6.79
Knee flexion ROM (°)	145.1±6.32
Knee extension ROM (°)	-1.77±4.42

517 Values are presented as mean ± standard deviation or number. BMI, body mass index; CES-D, Center for
518 Epidemiologic Studies Depression Scale ;GLFS-25, 25-question Geriatric Locomotive Function Scale; 5CST, 5-
519 time chair-stand test; OLST, one-legged stance test; TUG, timed up and go; ROM, range of motion.
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* indicates significant difference between decline and non-decline groups (* $p<.05$).

BMI, body mass index; CES-D, Center for Epidemiologic Studies Depression Scale; 5CST, 5-time chair-stand test; OLST, one-legged stance test; TUG, timed up and go; ROM, range of motion.

542 **Table 3. Logistic regression analysis for the locomotive dysfunction**
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	Model 1			Model 2			Model 3		
	Odds ratio	95% CI	P-value	Odds ratio	95% CI	P-value	Odds ratio	95% CI	P-value
Age (year)	1.01	0.96-1.06	0.728	1.00	0.95-1.05	0.989	1.01	0.95-1.06	0.816
Sex	0.98	0.42-2.27	0.978	0.95	0.41-2.21	0.903	0.98	0.42-2.30	0.972
BMI (kg/cm ²)	0.95	0.85-1.06	0.358	0.95	0.85-1.06	0.341	0.95	0.85-1.06	0.387
CES-D (score)				0.99	0.89-1.09	0.776	1.00	0.97-1.04	0.860
GLFS-25 total score at baseline (score)				1.06	1.02-1.10	0.002			
domains of GLFS-25_ pain (score)							1.14	1.02-1.27	0.022
domains of GLFS-25_ basic ADL (score)							0.94	0.82-1.07	0.357
domains of GLFS-25_ instrumental ADL (score)							1.07	0.85-1.35	0.542
domains of GLFS-25_ social function (score)							1.26	1.00-1.58	0.045
domains of GLFS-25_ mental health (score)							1.14	0.71-1.29	0.767
Handgrip strength (kg)	0.95	0.90-1.01	0.094	0.95	0.90-1.01	0.080	0.95	0.90-1.00	0.069
Hip flexion strength (Nm/kg)	4.72	1.20-18.5	0.026	4.37	1.08-17.6	0.038	4.25	1.03-17.5	0.045
Hip extension strength (Nm/kg)	1.01	0.76-1.36	0.915	1.02	0.76-1.37	0.879	1.05	0.78-1.42	0.745
Hip abduction strength (Nm/kg)	0.50	0.09-2.61	0.406	0.89	0.16-4.95	0.895	0.87	0.15-4.91	0.877
Knee extension strength (Nm/kg)	1.29	0.81-2.07	0.276	1.36	0.84-2.19	0.205	1.31	0.81-2.12	0.269
Toe flexion strength (kg)	0.99	0.94-1.03	0.559	0.98	0.94-1.03	0.491	0.99	0.94-1.03	0.604
5CST (sec)	1.06	0.93-1.21	0.350	1.03	0.90-1.18	0.608	1.04	0.91-1.19	0.524
OLST (sec)	0.99	0.98-1.00	0.065	0.99	0.97-1.00	0.073	0.99	0.97-1.00	0.063
TUG (sec)	0.82	0.60-1.13	0.227	0.74	0.53-1.03	0.072	0.79	0.57-1.11	0.179
30-s stair test (time)	1.03	0.98-1.08	0.202	1.03	0.99-1.08	0.173	1.03	0.99-1.08	0.166
Knee flexion ROM (°)	0.97	0.93-1.01	0.216	0.97	0.93-1.02	0.215	0.97	0.92-1.01	0.187
Knee extension ROM (°)	0.96	0.91-1.02	0.307	0.98	0.92-1.04	0.474	0.97	0.92-1.03	0.372

545 Model 1: Logistic regression analyses with the groups as the dependent variable and age, sex, BMI, and physical function as the independent variables.
546 Model 2: Logistic regression analyses with the groups as dependent variable and age, sex, BMI, CES-D, GLFS-25 total score at baseline, and physical function as
547 the independent variables.
548 Model 3: Logistic regression analyses with the groups as dependent variable and age, sex, BMI, CES-D, domains of GLFS-25 at baseline, and physical function as
549 the independent variables.
550 Bold type represents a statistically significant result.

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Table 4. Logistic regression analysis of the subcategories by age

	≤ 65 years						> 65 years					
	Model 1			Model 2			Model 1			Model 2		
	Odds ratio	95% CI	P-value	Odds ratio	95% CI	P-value	Odds ratio	95% CI	P-value	Odds ratio	95% CI	P-value
Age (year)	0.81	0.67-1.01	0.061	0.87	0.70-1.07	0.191	1.00	0.92-1.10	0.923	1.01	0.95-1.06	0.788
Sex	0.58	0.12-2.66	0.481	0.75	0.15-3.84	0.730	0.97	0.35-2.68	0.954	0.94	0.33-2.72	0.913
BMI (kg/cm²)	0.96	0.81-1.14	0.665	0.91	0.75-1.09	0.318	0.99	0.89-1.09	0.776	0.98	0.84-1.14	0.768
CES-D (score)				0.96	0.90-1.02	0.167				1.04	0.98-1.08	0.137
GLFS-25 at baseline (score)				1.14	1.05-1.24	0.001				1.02	0.98-1.07	0.291
Handgrip strength (kg)	0.94	0.86-1.03	0.191	0.95	0.86-1.04	0.287	0.94	0.88-1.01	0.095	0.94	0.88-1.01	0.117
Hip flexion strength (Nm/kg)	13.3	1.62-108	0.017	17.0	1.43-202	0.025	3.26	0.56-18.8	0.186	2.47	0.39-15.5	0.335
Hip extension strength (Nm/kg)	0.84	0.56-1.26	0.399	0.87	0.56-1.35	0.548	1.31	0.82-2.08	0.256	1.26	0.79-2.02	0.331
Hip abduction strength (Nm/kg)	0.38	0.03-4.83	0.458	0.40	0.02-6.37	0.517	0.59	0.06-5.60	0.649	0.85	0.08-9.47	0.894
Knee extension strength(Nm/kg)	1.09	0.56-2.13	0.786	0.97	0.46-2.01	0.930	1.54	0.78-3.05	0.216	1.66	0.83-3.35	0.153
Toe flexion strength (kg)	1.00	0.93-1.08	0.968	1.01	0.93-1.10	0.742	0.98	0.92-1.04	0.529	0.98	0.92-1.04	0.526
5CST (sec)	1.07	0.89-1.30	0.454	1.11	0.90-1.37	0.317	1.06	0.88-1.28	0.503	1.02	0.84-1.23	0.866
OLST (sec)	1.00	0.97-1.02	0.997	0.99	0.97-1.02	0.784	0.99	0.98-1.00	0.065	0.99	0.98-1.00	0.063
TUG (sec)	0.65	0.36-1.16	0.144	0.46	0.23-0.89	0.021	0.90	0.61-1.34	0.611	0.82	0.55-1.24	0.350
30-s stair test (time)	1.02	0.95-1.09	0.652	1.01	0.93-1.09	0.793	1.04	0.98-1.10	0.211	1.04	0.98-1.10	0.215
Knee flexion ROM(°)	0.98	0.91-1.06	0.622	0.93	0.85-1.04	0.202	0.98	0.93-1.03	0.403	0.97	0.92-1.03	0.362
Knee extension ROM(°)	1.00	0.92-1.09	0.977	1.02	0.93-1.14	0.581	0.94	0.87-1.02	0.128	0.94	0.87-1.02	0.144

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565 Model 1: Logistic regression analyses with the groups as the dependent variable and age, sex, BMI, and physical function as the independent variables.

566 Model 2: Logistic regression analyses with the groups as dependent variable and age, sex, BMI, CES-D, GLFS-25 at baseline, and physical function as the

567 independent variables.

568 Bold type represents a statistically significant result.