Differences in Gait Cycle and Biomechanical Lower-Limb Joint Function between Elderly People with and without Cognitive Decline

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Abstract: Because dementia is difficult to treat, the best way is to detect the prodromal stage; this can identify those at high risk of dementia and help to delay its onset. It is a well-known fact that gait has a high correlation with cognitive function. Considering that dementia starts with cognitive decline, investigating the association between cognitive decline and gait may contribute to the detection of elderly individuals at high risk of dementia and even the prevention of dementia. The purpose of the present study was to investigate the gait cycle and biomechanics of elderly people with and without cognitive decline. A three-dimensional motion analysis system was used, and older adults over 65 participated in this study. K-MoCA was used to assess cognitive function and, according to the results of a cognition function assessment, they were classified into two groups. Spatiotemporal variables, subdivisions of the gait cycle, joint angle, joint moment, joint power, and support moment were investigated. Significant differences between both groups appeared in the subdivisions of the gait cycle, and parameters of gait biomechanics were established. These results provide insight into the mechanism dictating the gait of elderly individuals with cognitive decline.

Keywords: cognitive decline; dementia; motoric cognitive risk syndrome; mild cognitive impairment; gait biomechanics; elderly

1. Introduction

With the increase in the population of people aged over 65, degenerative disease is increasing rapidly. Among degenerative diseases, dementia, in particular, is a worldwide issue. Although numerous studies and interventions have attempted to treat dementia, there are still no cases of cognitive reversion. Hence, the best approach is to detect dementia early and follow up with rehabilitative intervention. For this to succeed, it is important to identify the prodromal stage that suggests a high risk of progression to dementia.

Mild cognitive impairment (MCI) is the most frequently mentioned prodromal stage of dementia. MCI is a stage that shows objective cognition decline while the ability to independently conduct activities of daily living (ADL) is still preserved, and MCI has the potential for reversion to normal cognition [1–4]. However, it is very difficult to diagnose MCI because there are many common features between normal aging, MCI, and dementia.

Gait disorder is thought to be a marker for the risk of dementia [5,6]. Hence, the association between walking ability and cognitive decline is being widely investigated as an alternative approach to determine the prodromal stage of dementia or predict a high risk of dementia. Most of the previous studies [10–12] have investigated spatiotemporal variables of gait (i.e., gait speed, stride length, step length, cadence, stride time) and, as a result, slow gait speed was suggested as a major risk factor.
In other words, slow gait speed is considered to be an identifying factor for cognitive impairment, including MCI and dementia [2,13–15]. Furthermore, it has been reported that motoric cognitive risk syndrome (MCR), a state in which both subjective cognitive complaints and slow gait speed are present, increases the risk of dementia [16,17]. In addition, the co-occurrence of MCI and a slow gait has a high risk of dementia [6]. Although gait speed is useful in predicting cognitive decline and a high risk of dementia, it still has a limitation in that it lacks specificity [10].

Investigating the gait cycle and dynamic parameters may contribute to overcoming the insufficient specificity of gait speed and, furthermore, could serve as additional markers for predicting cognitive decline. In addition, it can help to assist in walking during daily life for elderly people who suffer from cognitive decline and can also provide clinical evidence for cognitive function interventions through gait training/exercise based on several pathological and medical imaging studies [7,18]. To our knowledge, there are no studies examining the gait cycle and biomechanical parameters of gait in elderly individuals with cognitive decline.

Therefore, the purpose of this study was to investigate the gait cycle and gait biomechanics of the elderly with and without cognitive decline by using three-dimensional motion analysis.

2. Materials and Methods

2.1. Participants

Seventy-five community-dwelling elderly people over 65 years of age participated in this study. All participants had no musculoskeletal disorders and were able to walk independently and to come by themselves to the place where this study would be conducted.

Before conducting the experiment, the investigators provided an oral and written explanation of the study to all participants, and then all participants voluntarily provided written informed consent. All participants performed cognitive function assessment. After finishing the cognitive assessment, they were asked to walk on level ground. All procedures in this study were approved by the Institutional Review Board of Jeonbuk National University (IRB File No. JBNU 2019-09-015-001).

2.2. Cognitive Function Assessment

To evaluate cognitive function, the Korean form of the Montreal cognitive assessment model (K-MoCA) was used. K-MoCA is a Korean version of the MoCA developed by Ziad Nasreddine, M.D., to screen for mild cognitive impairment.

All participants performed K-MoCA before walking on level ground. All participants were classified into either a normal cognitive function group (NC) and a lower cognitive function group (LC) according to their K-MoCA score, and the cut-off point differs according to the years of education and age of each participant [19].

2.3. Level Walking Capture and Experimental Instruments

After the cognitive function evaluation was completed, all participants performed level-ground walking. Each participant walked at a preferred self-selected speed on a flat walkway of at least 10 m. To capture each participant’s level-ground walking, a three-dimensional marker-based optical motion capture system was used. A total of fifteen active infrared light-emitting diode markers (IREDs) were attached to the lower extremity joint, according to the motion module marker guide (MusculoGraphics, Inc., Santa Rosa, CA, USA). Three position sensors (Optotrak Certus, Northern Digital Inc., Waterloo, ON, Canada) and four force plates (4060-08, Bertec Co., Ltd., Columbus, OH, USA) were used to collect IREDs signals and ground reaction forces, respectively.
2.4. Gait Analysis

In this study, spatiotemporal variables, kinematics and kinetics were analyzed as outcome parameters. All spatiotemporal variables, kinematics and kinetics of the lower extremity joints were calculated using the software for interactive musculoskeletal modeling (SIMM, MusculoGraphics Inc., Santa Rosa, CA, USA), and the support moment was calculated according to Winter [20]. The support moment is equal to the sum of the extensor moments at the ankle, knee, and hip, and represents the total motor pattern of the lower limb [21].

The spatiotemporal variables are as follows: stride length, step length, cadence, gait velocity, the proportions of subdivisions of the gait cycle (i.e., loading response (LR), midstance (MSt), terminal stance (TSt), pre-swing (PSw), single limb support (SLS), and double limb support (DLS)) [22]. The parameters of kinematics and kinetics are as follows: joint angle, joint angular displacement, joint moment, joint power, and support moment.

Joint moment, support moment, and joint power were normalized to each participant’s body mass, and the gait cycle (from the initial contact to initial contact of the ipsilateral leg) was normalized from 0% to 100%. The gait profiles of kinematics and kinetics for each participant, as derived during the three trials, were ensemble-averaged. The peak angle, angular displacement, and means of joint moment and power were also derived from the three trials of each participant and were averaged.

2.5. Statistical Analysis

All outcome measures were tested for normality using the Shapiro–Wilk test. Based on those normality test results, to test the statistically significant difference between both groups, the parameters with normal distribution were assessed using an independent t-test, and parameters with non-normal distribution were established using the Mann–Whitney U-test. The level of statistical significance was set at \( p < 0.05 \). Statistical analyses were conducted using the IBM® SPSS® 20 (IBM Corp., New York, NY, USA).

3. Results

3.1. Demographics

Table 1 shows the age, height, weight, years of education, and K-MoCA scores of the two groups.

| Groups | n  | Age (yrs.) ± standard deviation | Height (cm) ± standard deviation | Weight (kg) ± standard deviation | Education (yrs.) ± standard deviation | Score ± standard deviation |
|--------|----|---------------------------------|----------------------------------|---------------------------------|--------------------------------------|--------------------------|
| NC     | 48 | 74.3 ± 3.7                      | 167.4 ± 5.9                      | 66.6 ± 8.9                      | 13.4 ± 3.0                           | 23.7 ± 2.8               |
| LC     | 27 | 76.1 ± 4.7                      | 166.3 ± 6.0                      | 66.0 ± 8.0                      | 13.6 ± 3.3                           | 18.5 ± 3.4†              |

Mean ± standard deviation; † indicates statistical significance via a Mann–Whitney-U test, \( p \)-value < 0.05; NC: normal cognitive function group; LC: lower cognitive function group.

On the one hand, the LC group showed a significantly lower K-MoCA score (\( p \)-value < 0.001). On the other hand, although the LC group was older and shorter than the NC group, there was no statistical significance between the two groups, and the weights and years of education were similar. Therefore, age, height, and weight were not considered in the statistical analysis of the gait variables of the two groups.

3.2. Spatiotemporal Parameters and Subdivisions of the Gait Cycle

Tables 2 and 3 show the differences in spatiotemporal parameters and subdivisions of the gait cycle between the two groups.
Table 2. Spatiotemporal parameters between both groups.

| Groups | Stride Length (cm) | Step Length (cm) | Cadence (Steps/min) | Gait Velocity (cm/s) |
|--------|-------------------|------------------|---------------------|----------------------|
| NC     | 126.2 ± 10.3      | 65.3 ± 5.9       | 111.1 ± 7.6         | 117.1 ± 14.8         |
| LC     | 123.0 ± 9.1       | 63.3 ± 5.3       | 108.0 ± 7.4         | 110.9 ± 13.1         |

Mean ± standard deviation; NC: normal cognitive function group; LC: lower cognitive function group.

Table 3. Differences of the subdivisions of gait cycles between the normal cognition group and lower cognition group.

| Groups | LR (%) | MSt (%) | TSt (%) | PSw (%) | SLS (%) | DLS (%) | SP (%) |
|--------|--------|---------|---------|---------|---------|---------|--------|
| NC     | 10.5 ± 1.3 | 21.2 ± 2.5 | 18.4 ± 2.8 | 11.1 ± 1.2 | 39.5 ± 1.3 | 21.6 ± 2.3 | 38.8 ± 1.4 |
| LC     | 11.3 ± 1.3 † | 19.9 ± 2.4 * | 18.9 ± 2.5 | 11.6 ± 1.0 | 38.9 ± 1.2 * | 22.9 ± 2.0 * | 38.2 ± 1.2 |

Mean ± standard deviation; NC: normal cognitive function group; LC: lower cognitive function group; LR: loading response; MSt: mid-stance phase; TSt: terminal stance phase; PSw: pre-swing phase; SLS: single limb support; DLS: double limb support; SP: swing phase; † indicates statistical significance via the Mann–Whitney-U test, p-value < 0.05; * indicates statistical significance via an independent t-test, p-value < 0.05.

There was no statistical significance between the two groups regarding spatiotemporal variables, but the LC group had a lower gait performance than the NC group. However, there was a significant difference between the two groups in the subdivisions of the gait cycle. Compared with the NC group, the LC group had a longer LR (p-value = 0.020) and DLS (p-value = 0.029), and a shorter MS (p-value = 0.043) and SLS (p-value = 0.033).

3.3. Gait Profiles of Lower-Limb Joints between the Two Groups

Figure 1 shows the profiles of lower extremity joints in two groups during level walking.

Although the joint angle, moment, and power patterns of the two groups were similar, there were differences in the peak and specific period means. For example, regarding the joint angle, the difference between peak ankle angle (i.e., pAA-2) and ankle angle displacement (i.e., AAD-1) was clear. Regarding the joint moment, there was a difference between peak knee moment (i.e., pKM-1) and mean knee extensor moment (i.e., mKEM). There was a difference in joint power between the hip joint (i.e., pHP-1, mHPP-1 and pHP-3) and the knee joint (i.e., pKP-0, pKP-2 and mKPP-0). The moment of support from the MSt to the TSt was lower in the LC group than in the NC group.
Although the joint angle, moment, and power patterns of the two groups were similar, there were differences in the peak and specific period means. For example, regarding the joint angle, the difference between peak ankle angle (i.e., $p_{AA}-2$) and ankle

**Figure 1.** Profiles of the joint biomechanics of the two groups. (a) Hip joint angle; (b) knee joint angle; (c) ankle joint angle; (d) hip joint moment; (e) knee joint moment; (f) ankle joint moment; (g) hip joint power; (h) knee joint power; (i) ankle joint power; (j) support moment. A positive value in the profiles of the joint angle and joint moment indicates joint flexion and joint flexor moment, respectively; a positive value in the profiles of joint power and support moment indicates energy generation and the sum of the extensor moment, respectively.
3.4. Parameters of Kinematics and Kinetics in the NC and LC

Tables 4 and 5 show the difference between the peak angles and angular displacements of the two groups. At peak joint angles, the LC group showed greater dorsiflexion during the PSw than the NC group (i.e., pAA-2, p-value = 0.041). Similarly, the LC group exhibited more ankle joint flexion during the TS (i.e., AAD-1, p-value = 0.025). There was no statistical significance found in the other parameters.

Table 4. Peak joint angle parameters in both groups.

| Groups | pHA-1 | pHA-2 | pHA-3 | pKA-1 | pKA-2 | pKA-3 | pAA-1 | pAA-2 | pAA-3 | pAA-4 |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| NC     | 35.8 ± 5.3 | -9.4 ± 4.8 | 38.2 ± 5.5 | 28.5 ± 6.3 | 11.0 ± 6.8 | 76.3 ± 3.6 | 3.1 ± 4.0 | 26.7 ± 2.9 | -1.0 ± 6.0 | 12.3 ± 3.3 |
| LC     | 35.6 ± 4.5 | -9.4 ± 4.9 | 38.6 ± 5.3 | 27.6 ± 6.0 | 10.0 ± 7.5 | 76.5 ± 4.3 | 2.3 ± 2.5 | 27.7 ± 3.1† | -0.1 ± 4.9 | 12.1 ± 3.3 |

Mean ± standard deviation. NC: normal cognitive function group; LC: lower cognitive function group; † indicates statistical significance via Mann–Whitney-U test, p-value < 0.05; pHA: peak hip joint angle; pKA: peak knee joint angle; pAA: peak ankle angle.

Table 5. Joint angular displacements in both groups.

| Groups | HAD-1 | HAD-2 | KAD-1 | KAD-2 | AAD-1 | AAD-2 | H-ROM | K-ROM | A-Rom |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| NC     | 45.2 ± 4.5 | 47.6 ± 3.9 | 17.5 ± 6.0 | 65.3 ± 7.0 | 23.5 ± 3.4 | 27.7 ± 4.7 | 48.0 ± 4.1 | 67.6 ± 5.9 | 28.5 ± 3.8 |
| LC     | 45.0 ± 4.7 | 48.1 ± 4.9 | 17.6 ± 6.7 | 66.5 ± 7.0 | 25.4 ± 3.3* | 27.9 ± 5.5 | 48.2 ± 4.7 | 68.5 ± 5.7 | 29.1 ± 4.7 |

Mean ± standard deviation. NC: normal cognitive function group; LC: lower cognitive function group; * indicates statistical significance via an independent t-test, p-value < 0.05; HAD: hip joint angular displacement; KAD: knee joint angular displacement; AAD: ankle joint angular displacement; H-ROM: displacement from maximal hip flexion angle to maximal hip extension angle; K-ROM: displacement from maximal knee flexion angle to maximal knee extension angle; A-ROM: displacement from maximal dorsiflexion angle to maximal plantarflexion angle.

Tables 6 and 7 show the mean joint moment and joint power. The mean knee positive power of the LC group was lower than that of the NC group during the LR (i.e., mKPP-0, p-value = 0.014), and the mean ankle extensor moment (i.e., mAEM, p-value = 0.014) after the LR was lower than that of the NC group. In addition, the mean hip positive power (i.e., mHPP-2, p-value = 0.035) during the PSw was lower than that of the NC group. There were differences between the two groups in other parameters except for mKPP-0, mAEM, and mHPP-2 as well, but there was no statistical significance.

Table 6. Mean joint moments in the NC and the LC.

| Group | mHEM | mHFM | mKFM | mKEM | mAEM | mAEM | mSM |
|-------|------|------|------|------|------|------|------|
| NC    | -0.48 ± 0.10 | 0.22 ± 0.05 | 0.19 ± 0.06 | -0.32 ± 0.11 | 0.10 ± 0.03 | -0.70 ± 0.07 | 0.94 ± 0.18 |
| LC    | -0.43 ± 0.10 | 0.20 ± 0.05 | 0.17 ± 0.07 | -0.29 ± 0.11 | 0.09 ± 0.03 | -0.64 ± 0.09† | 0.88 ± 0.18 |

Mean ± standard deviation. NC: normal cognitive function group; LC: lower cognitive function group; † indicates statistical significance via the Mann–Whitney-U test, p-value < 0.05; mHEM: mean hip extensor moment; mHFM: mean hip flexor moment; mKFM: mean knee flexor moment; mKEM: mean knee extensor moment; mAEM: mean ankle extensor moment; mSM: mean support moment.

Table 7. Mean joint powers in the NC and the LC.

| Group | mHPP-1 | mHPP-2 | mKPP-0 | mKNP | mKPP-1 | mANP | mAPP | Hip Total | Knee Total | Ankle Total |
|-------|--------|--------|--------|------|--------|------|------|----------|-----------|-------------|
| NC    | 0.64 ± 0.32 | 0.53 ± 0.35 | 0.41 ± 0.38 | -0.59 ± 0.42 | 0.29 ± 0.43 | -0.47 ± 0.45 | 1.25 ± 0.46 | 0.44 ± 0.48 | 0.38 ± 0.49 | 0.38 ± 0.49 |
| LC    | 0.20 ± 0.22† | 0.15 ± 0.22† | 0.21 ± 0.22† | 0.33 ± 0.22† | 0.15 ± 0.22† | -0.42 ± 0.22† | 1.16 ± 0.22† | 0.41 ± 0.22† | 0.36 ± 0.22† | 0.34 ± 0.22† |

Mean ± standard deviation. NC: normal cognitive function group; LC: lower cognitive function group; † indicates statistical significance via an independent t-test, p-value < 0.05; mHPP: mean hip positive power; mKPP: mean knee positive power; mKNP: mean knee negative power; mAEM: mean ankle extensor moment; mSM: mean ankle positive power; Hip Total: absolute hip positive power plus absolute hip negative power; Knee Total: absolute knee positive power plus absolute knee negative power; Ankle Total: absolute ankle positive power plus absolute ankle negative power.
4. Discussion

All the participants were examined using the K-MoCA and classified into a normal cognition group or a lower cognition group, according to the cut-off point. Their walking on level ground was captured using a three-dimensional motion capture system; then, the gait parameters of spatiotemporal movement, kinematics, and kinetics were analyzed.

4.1. Biomechanical Gait Pattern of Elderly People with Lower Cognitive Function

Although statistical significance between the two groups did not appear in the spatiotemporal parameters, the LC group showed lower gait performance compared to the NC group (Table 2). However, subdivisions of the gait cycle showed significant differences between the LC group and the NC group (Table 3). Compared with the NC group, the LC group had a shorter SLS and longer DLS, which was attributed to the change in the ratio of the LR and the MSt. The LC group showed a longer LR and shorter MSt than those of the NC group. Considering that only cognitive function showed a statistically significant difference between the two groups (Table 1), this means that the neuromotor control of the gait is different according to the status of cognitive function.

In the LR, the LC group showed lower knee extensor moment and power than the NC group, whereas the hip joint showed higher extensor power (Figure 1). During the LR, tasks such as weight shifting and shock absorption are performed and, if these tasks are unsuccessful, a fall may be induced. The work of the concentric contraction of the knee extensor for shock absorption [23] was small in the early LR (i.e., mKPP-0 in Table 7). To compensate for this, the positive work of the hip extensor was in a burst (i.e., pHP-1 in Figure 1g).

In the MS, the hip extensor work of the LC group was rapidly decreasing, unlike the maintained hip positive power of the NC group (Figure 1g). In particular, the LC group presented lower knee extensor moment and power than the NC group (Figure 1e,h). Although there is no statistical significance, it can be seen that the mKEM and mKPP-1 of the LC group are lower than in the NC group, as shown in Tables 6 and 7. During the MSt, the upright alignment of the segments of single-leg movement that supports the body must be achieved and maintained. Therefore, the low knee extensor moment and power of the LC groups means that the activation of the knee extensors of the LC group is lower than in the NC group. In other words, this means that the quadriceps muscle function was lower in the LC group than in the NC group. Hortobágyi et al. [24] reported that the function of the quadriceps muscles decreases with aging. This low activation of the knee extensor can merely be regarded as a result of aging, but there was no statistical difference in age between the two groups. In other words, elderly people with cognitive decline show lower knee extensor function than elderly people without cognitive decline.

In the second half of the stance phase (i.e., the TSt–PSw), the LC group presented more dorsiflexion and lower hip flexor power. pAA-2 and AAD-1 in Tables 4 and 5 show that the ankle joint is flexing more in the LC group than in the NC group from the TSt to PSw. This dorsiflexion leads to a faster initial contact of the contralateral limb and might contribute to the reduction of step length, as shown in Table 2. In addition, pHP-3 and mHPP-2 were lower in the LC group. Given that mHFM was similar between both groups, it can be presumed that the angular velocity of the femur, which is flexing when entering the swing phase, is lower in the LC group and thus contributes to a decrease in stride length. This can be attributed to the reduced positive power of plantarflexion in the PSw (Figure 1i).

To summarize, significant differences between both groups were found in the subdivisions of the gait cycle. Furthermore, biomechanical differences were also found. The LC group has a longer DLS and LR and shorter SLS and MSt than the NC group. In the LR, MSt, and push-off, the extensor activity of the three lower-extremity joints was different between the two groups.
4.2. Gait Adaptation According to Cognitive Function Decline

The LC group had a slower walking speed, longer DLS and shorter SLS, compared to the NC group. As mentioned in Section 4.1, this difference results from the change in the ratio of the LR and the MST and the difference in the motor control pattern. This gait, as exhibited by the LC group, may be an adaptation to further ensure gait stability.

In DLS, including LR and PSw, the movement speed of the center of mass (COM) is the fastest. At this time, if the push-off function increases while pAA-2 decreases, the COM movement will be further accelerated. If the movement speed of COM is further accelerated, lower limb collapse may be induced during the first half of the stance phase, as inferred from the low support moment of the LC group. However, in the LC group, pAA-2 increased and mAEM decreased during push-off. That is, as dorsiflexion increases, the upward and forward acceleration of COM decreases, and as the plantar flexor moment decreases, forward propulsion through the push-off decreases. There was also no difference between the two groups in pAA-3 and AAD-2. This means that no extension occurred to counter the more flexed ankle joint. If extension occurs, as mentioned earlier, the COM accelerates further forward and upward, resulting in a higher movement speed, which can lead to instability. This may be supported by pAP-4, which shows that the energy generation for forward propulsion through extension is low.

The shorter SLS of the LC group is due to the reduced MST proportion. In the MST, while one leg supports the body, the body moves forward and an upright stand alignment of segments of the supporting leg is achieved. At this moment, the supporting leg must support the body while maintaining postural balance. The shorter MST of the LC group would be a strategy to reduce this phase to induce double limb support quickly, thereby securing gait stability.

This gait adaptation of the LC group is consistent with the gait changes that occur with aging. Several studies [21,25,26] related to gait in the elderly have reported that walking speed slows, DLS lengthens, and SLS shortens with age. However, there was no statistical difference in age among the subjects who participated in this study. Thus, the differences shown by the LC group were due to the level of cognitive function, not age. In other words, this suggests that the lower the cognitive function, the more trying it is to secure the stability of gait.

Perhaps this gait adaptation is due to lower postural balance or lower quadriceps/biceps femoris function. First, there are many studies reporting a positive association between decreased cognitive function and decreased vestibular function [27]. The vestibular sensory function, as is well known, is the main sensory system that regulates postural balance. An adaptation of the LC group may be the result of a low vestibular sensory function. Therefore, in future studies, it will be necessary to investigate vestibular sensory function in the subjects who participated in this study and to reveal its relationship with gait adaptation.

Second, as shown in Figure 1, pKM-1 and mKEM were lower in the LC group than in the NC group. In addition, the knee extensor power is low during the LR to MST. Furthermore, the support moment was significantly lower in the LC group than in the NC group, indicating that this difference is due to the knee extensor. That is, it can be inferred that the ability of the knee extensor to support the body while maintaining balance with the single lower extremities was lower in the LC group. These results can suggest clinical evidence that knee joint muscles should be trained/supported when performing walking exercises, to protect against progression to dementia, and to assist gait in the daily life of elderly people who suffer from cognitive decline. To further confirm this, further studies analyzing EMG are needed.

The present study has some limitations as follow: (1) The number of subjects who participated in this study is small, compared with the previous study and, in particular, the number of samples of the LC group were smaller than those in the NC group; hence, it is necessary to recruit more elderly participants and then investigate the differences between both groups.
(2) Only the parameters in the sagittal plane were investigated in the present study. Thus, it is necessary to examine the variables of the non-sagittal plane (i.e., hip rotation, hip abduction), because those parameters can provide stability to the trunk and postural perturbation during the gait.

(3) In addition, in order to investigate the causes of gait adaptation in the elderly regarding cognitive decline in the central nervous system domain, it will be necessary to investigate various sensory and cognitive functions.

5. Conclusions

To our knowledge, there are no studies examining the gait cycle, kinematics, and kinetics of gait in elderly people with a decline in cognitive function. In this study, we classified elderly people with low cognitive function through the application of the K-MoCA and then analyzed their gait using a three-dimensional motion analysis technique. As a result, it was confirmed that there was a difference between the two groups regarding the subdivisions of the gait cycle and joint mechanics. The results are as follows:

- Older adults with reduced cognitive function have slower walking speeds, longer DLS cycles, and shorter SLS cycles than those with normal cognitive function.
- During LR to MSt, the function of the femoral muscles was lower in the LC group, which was compensated by the hip extensors, and the plantar flexor’s function is low during push-off.
- In conclusion, elderly people with cognitive function decline adopt a gait strategy to secure gait stability.

These results provide clinical evidence of the effectiveness of assistance/rehabilitation in gait training for the prevention of dementia progression and safe daily walking in elderly people with cognitive decline.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of Jeonbuk National University (IRB File No. JBNU 2019-09-015-001), and this present study was registered in Clinical Research Information Service (CRIS) (Trial registration number, KCT0006202).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study, and written informed consent has been obtained from the participants to publish this paper.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to their also forming part of an ongoing study.

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