Editorial

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Review Article

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Original Articles

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Applying ICF Framework to Explore the Factors That Influence Quality of Life in Patients After Lung Surgery

Influence of Sex on Cognitive and Motor Dual-Task Performance Among Young Adults: A Cross-Sectional Study
Aims and Scope

Annals of Rehabilitation Medicine (ARM) is the official journal of the Korean Academy of Rehabilitation Medicine. It is an international, peer-reviewed open access journal, which aims to be a global leader in sharing up-to-date knowledge dedicated to the advancement of care and enhancing the function and quality of life of persons with various disabilities and chronic illnesses. As the official journal of one of the largest societies of rehabilitation medicine in Asia and Oceania, nearly 8,000 physiatrists receive this journal every two months as a member benefit. This journal is endorsed by the International Society of Physical and Rehabilitation Medicine (ISPRM) and the Asia-Oceanian Society of Physical and Rehabilitation Medicine (AOSPRM). International members comprise approximately half the editorial board and conduct peer-review of submitted manuscripts.

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This journal was supported by the Korean Federation of Science and Technology Societies Grant funded by the Korean Government (Ministry of Education).
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Balance has been recognized as a crucial factor, as it involves maintaining posture during static stance and transitioning between movements, and it plays a significant role in performing daily activities. Consequently, numerous studies have been conducted to evaluate balance ability over the years [1].

The Berg Balance Scale (BBS) is the best-known balance measure that assesses balance and fall risk in adults. The BBS consists of 14 items with an ordinal scale of 0 to 4 for a total of 56 points (a lower score indicates higher fall risk). Zero score indicates the lowest level of function and 4 score the highest level of function and it takes approximately 20 minutes to complete. The items evaluate from the static position with increasing difficulty by decreasing the base of support to dynamic activities. The BBS is designed with content closely resembling real-life daily activities, making it easy to learn and allowing for repetitive evaluations. It requires minimal cost, time, and simple equipment [2-4]. Additionally, even patients in the acute phase of stroke, many of whom may be unable to sit or stand, can undergo the assessment, highlighting its advantages [4].

The clinical utility of the BBS includes the ability to estimate rehabilitation outcomes using the total score of the scale. Research on estimating rehabilitation outcomes suggests that scores measured at admission using the BBS are inversely related to the length of hospitalization and can predict the duration of hospitalization and eventual discharge decisions [5]. Additionally, studies have categorized functional levels based on scores; for instance, scores ranging from 0 to 20 indicate the ability to walk with a walking aid, scores from 21 to 40 suggest the ability to walk with assistance, and scores from 41 to 56 indicate independent walking capability [6]. The BBS also serves as a predictor of fall risk, with scores of 41–56 indicating low risk, 21–40 indicating medium risk, and 0–20 indicating high risk [7].

Berg et al. [3,4] reported that the reliability of the BBS was 0.83 as measured by Cronbach’s alpha coefficient in a study involving the general elderly population, and 0.97 in a study involving stroke patients, indicating high reliability (Table 1). This suggests that the BBS may be particularly useful for assessing balance in stroke patients, showing higher reliability in this population compared to its original purpose of assessing fall risk in the elderly. The BBS has been validated for use in individuals with spinal cord injury and has the advantage of being valuable for other neurologic populations [8]. The Korean version of BBS has also been verified for validity and reliability [9].
The minimal clinically important difference (MCID) for balance improvement was 13.5 points in stroke patients, indicating that the BBS MCID does clinically detect changes in balance abilities in persons with stroke [10].

There are limitations in the BBS. The BBS doesn’t measures the quality of gait and the speed of walking, therefore, may be less useful than other tools where motor control is a bigger contributor to poor balance than muscle weakness. It also has a ceiling effect in younger people (<75) who have balance problems even if they have an increased risk of falling. [11].

In conclusion, the BBS is a useful outcome measure in predicting the risk of falls, assessing balance deficits, providing a numerical score that can be tracked for improvement over time, and even assessing the length of stay at inpatient rehabilitation.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

FUNDING INFORMATION

None.

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INTRODUCTION

Thoracic radiculopathy (TR) is commonly characterized by direct anatomic compression or irritation of exiting spinal nerve roots in the thoracic spine. Clinically it presents with localized pain or paresthesia in the back, chest, or abdomen that follows a dermatomal pattern corresponding to the affected spinal level [1]. Truncal or abdominal muscle weakness in a myotomal distribution may be present [1]. TR pain represents approximately 5% of outpatient pain clinic referrals [2]. Thoracic disc disease

To evaluate the efficacy of physical therapy (PT) to alleviate symptomatic thoracic radiculopathy (TR) without the use of invasive procedures. Database search was conducted by an experienced medical librarian from inception until January 27, 2023, in EBSCO CINAHL with Full Text, Ovid Cochrane Central Register of Controlled Trials, Ovid Embase, Ovid MEDLINE, Scopus, and Web of Science Core Collection. Inclusion criteria included studies that involved adult patients (age ≥18) who had a magnetic resonance imaging-confirmed TR and underwent a structured, supervised PT program of any length. All types of studies were included. Study quality and risk of bias were assessed using the National Heart, Lung, and Blood Institute (NHLBI) Study Quality of Assessment Tool. Certainty in evidence was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach. A meta-analysis was not performed. A total of 1,491 studies were screened and 7 studies met inclusion criteria, 5 case studies and 2 cohort studies. All studies showed improvement or resolution of the TR with PT. Quantitative improvements were not noted in most studies and PT regimens were sparsely described. Overall quality assessment demonstrated 3 studies had "good," 1 "fair," and 3 "poor" quality evidence. Certainty of evidence was "low" due to risk of bias. A dedicated PT program may help to alleviate symptomatic TR; however due to limited evidence, risk of bias, and low certainty in evidence, the data is too weak to support a definite conclusion.

Keywords: Systematic review, Thoracic diseases, Physical therapy modalities, Radiculopathy, Thoracic vertebrae
specifically is involved in only 0.15%–4% of symptomatic disc herniations of the spine and they represent <2% of all spinal disc surgeries performed [1].

The treatment for TR varies greatly depending on the etiology. Initial conservative treatment with rest and oral analgesics is often recommended. If symptoms progress or conservative measures fail, percutaneous interventional pain control modalities or surgical decompression may be considered. There is limited data available on the treatment of TR solely with physical therapy (PT); however, PT modalities such as dynamic stretching, manual therapy, and postural training have gained recognition as potentially effective management options [3].

To ensure evidence-based recommendations exist and are provided to patients, this systematic review aims to evaluate the efficacy of PT to alleviate symptomatic TR without the use of invasive procedures. The authors seek to contribute to the existing body of medical knowledge and inform clinical practice in the management of this condition as this is the first systematic review and meta-narrative analysis regarding this topic.

METHODOLOGY

Study protocol
Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were followed when performing this systematic review [4]. The protocol was submitted in the International Prospective Register for Systematic Reviews (PROSPERO) database on February 7, 2023. It was registered with the most recent edit on February 18, 2023, under the following ID number, CRD42023397753 [5].

Search strategy
The literature was searched by a medical librarian for the concepts of TR and PT. Search strategies were created using a combination of keywords and standardized index terms. Searches were run on January 27, 2023, in EBSCO CINAHL with Full Text (1963+), Ovid Cochrane Central Register of Controlled Trials (1991+), Ovid Embase (1974+), Ovid MEDLINE (1946+ including epub ahead of print, in-process & other non-indexed citations), Scopus (1788+), and Web of Science Core Collection (Science Citation Index Expanded 1975+ & Emerging Sources Citation Index 2015+). After removing pediatric studies based on the exclusion criteria, a total of 2,148 citations were retrieved. One additional text was found independently. Duplicates were removed using Covidence (Covidence systematic review software; Veritas Health Innovation, available at www.covidence.org) leaving 1,491 citations. Full search strategies are provided in Supplementary Table S1.

Study selection process
Studies were selected for our paper if they included adult patients (age≥18) who had an magnetic resonance imaging (MRI)-confirmed TR and underwent a structured, supervised PT program of any length. All types of studies were included. Studies were excluded if they involved children (age<18) or adults without an MRI-confirmed TR. They were also excluded if the patients underwent advanced interventional procedures including but not limited to epidural steroid injections, laminectomies, disc decompressions, spinal cord stimulators, and/or radiofrequency ablations alone or prior to a PT regimen.

In the first phase of the systematic review, each title and abstract identified by the expert librarian were evaluated in duplicate by two of the four independent reviewers (K.A.M., P.T.D., J.P., J.D.H.). Disagreements at this phase were resolved between the two reviewers and a third independent reviewer from the same group via consensus. In the second review phase, two of the four independent reviewers then screened the full texts of each study procured by the first phase. The full texts were reviewed in duplicate, and disagreements were resolved by consensus between the two reviewers and a third independent reviewer. A unanimous decision between the three reviewers was required to include each paper. The references of each included article were screened for other relevant articles for inclusion. One article was found and included.

Data extraction
Data were extracted by four independent reviewers (K.A.M., P.T.D., J.P., J.D.H.) utilizing Covidence with each article evaluated in duplicate. Disagreements were discussed between the two reviewers and a unanimous consensus was reached prior to inclusion. The following data were extracted: (1) reference study, (2) population description, (3) description of symptoms, (4) pain improvement, (5) functional improvement, (6) symptomatic relief, (7) other relief, and (8) description of PT regimen (Table 1). Due to the type of selected studies, qualitative data was obtained and summarized in a descriptive manner [6,7].

Risk of bias and methodological quality assessment
Risk of bias was evaluated by four independent reviewers (K.A.M., P.T.D., J.P., J.D.H.) using the National Heart, Lung, and
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<th>Description of symptoms</th>
<th>Pain improvement</th>
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<th>Other relief</th>
<th>Description of PT regimen</th>
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<tr>
<td>Brown et al. [3]</td>
<td>Patients with symptomatic MRI-confirmed thoracic disc herniations aged 19–83 years old and a mean age of 48. 26 males and 29 females were included</td>
<td>&quot;Band-like&quot; chest pain, weakness, interscapular pain, epigastic pain, lower extremity pain, paresthesias</td>
<td>Not reported</td>
<td>77% of patients in the nonoperative group returned to previous level of activity. Of these, 61% had to modify activity level to some degree</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Hyperextension strengthening, postural training, body mechanics education</td>
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<td>Valentas et al. [15]</td>
<td>48-year-old female with T9 butterfly vertebra causing neuroforaminal narrowing and nerve root irritation</td>
<td>3 weeks of right flank pain with radiation to the abdomen and back, aching in nature</td>
<td>Unquantified improvement with continued pain present at 6 months</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Not described</td>
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<tr>
<td>Sundar and Rho [14]</td>
<td>33-year-old male with thoracic disc protrusion</td>
<td>Pain radiating from thoracic spine to anterior chest wall and down left upper extremity, numbness/tingling in the fingers, decreased sensation down arm</td>
<td>Not reported</td>
<td>Not reported</td>
<td>70%-80% symptom improvement</td>
<td>Not reported</td>
<td>McKenzie physical therapy focusing on cervical and thoracic extension-based exercise</td>
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<tr>
<td>Pirti et al. [13]</td>
<td>100 females in Ankara, Turkey with non-cyclic breast pain who were found to have MRI abnormalities involving cervical and/or thoracic discs affecting nerve roots</td>
<td>Non-cyclic breast pain continuing throughout the day and lasting at least 3 months</td>
<td>5 patients had mild to moderate improvement, 55 patients showed significant improvement, and 29 patients achieved complete pain remission. Decrease of average VAS pain score from 7.06 to 1.11</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Breakdown of relief by cervical vs. thoracic disc pathology is not provided</td>
<td>No description available</td>
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<td>Kato et al. [16]</td>
<td>Two professional Japanese baseball pitchers in their 20s with ossification of the ligamentum flavum causing thoracic radiculopathy with no myelopathic symptoms</td>
<td>Intractable chest pain, upper abdominal pain, dermatomal numbness</td>
<td>Painful symptoms gradually resolved</td>
<td>Patient 1 returned to physical exercise 2 weeks after initiation of treatment and achieved top condition by 4 months. Patient 2 returned to play in top condition 6 weeks after onset</td>
<td>Sensory changes gradually resolved</td>
<td>Patient 1 had recurrence of symptoms 7 years after initial presentation and conservative measures did not improve his symptoms, requiring him to change jobs. Patient 2 did not have recurrence of symptoms</td>
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<td>Hurh and Rho [12]</td>
<td>65-year-old male with T9-T10 disc extrusion</td>
<td>Aching, stabbing, and tight thoracic rib pain with radiation to anterolateral chest wall, lateral abdominal muscle bulging</td>
<td>100%</td>
<td>100%; pain free ADLs</td>
<td>Abdominal bulge was persistent but improving at 6 months</td>
<td>Not reported</td>
<td>Not reported</td>
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<td>Fitzpatrick et al. [11]</td>
<td>Healthy, active 57- and 67-year-old adult males with thoracic disc herniation and protrusion</td>
<td>Thoracolumbar region pain, severe muscle spasms, localized abdominal swelling, radiating inguinal/ groin pain, insidious mid-back pain, thoracic allodynia, pain with spinal rotation and/ or flexion</td>
<td>Patient 1: complete resolution after 8 months; Patient 2: 90% resolution at 5 months</td>
<td>Patient 1: gradual return to normal activity</td>
<td>Patient 2: decreased allodynia</td>
<td>Not reported</td>
<td>Gradual, guided return to normal spinal activity</td>
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PT, physical therapy; MRI, magnetic resonance imaging; VAS, visual analogue scale; ADLs, activities of daily living.
Blood Institute (NHLBI) Study Quality Assessment Tools for observational studies [8]. Case reports were evaluated for risk of bias by the tool put forth by Murad et al. [9] in the British Medical Journal. Each article was assessed by two independent reviewers and consensus was reached between the two when disagreements were found.

**Certainty in evidence**

Certainty in evidence was evaluated utilizing the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach [6,7].

**Evidence synthesis**

There was a lack of consistent, objective, and well described methods, measures, and reported results within and between the studies included, thus a meta-analysis could not reasonably be performed. The authors instead opted to summarize the findings with a meta-narrative approach (a qualitative systematic-review of mixed-method research). This is indicated when the key clinical factors vary among studies and a variety of methods are used [10].

**RESULTS**

**Characteristics of included studies**

A flow diagram of the study selection process is shown in Fig. 1. Seven studies met criteria for inclusion in this review [3,11-16]. None were randomized controlled trials (RCTs) and five were case studies [11,12,14-16]. The remaining two were a prospective cohort study and a retrospective cohort study [3,13]. Patient characteristics are described below in the meta-narrative of included studies.

**Risk of bias and methodological quality assessment**

The overall study quality assessment demonstrated three studies had “good” quality [12,14,16], one had “fair” quality [11], and three had “poor” quality of evidence [3,13,15] using the NHLBI Study Quality Assessment Tool for Observational Studies (Figs. 2-4) [8,9,17]. Only one of the case studies demonstrated a challenge/rechallenge phenomenon, and none of them had any dose response effect recorded. For the cohort studies identified, statistical evidence and blinding was lacking, exposures were measured only one time, and adjustments were not made for many possible confounding variables. Additionally, sample size justification, objective outcome measures, and properly described PT regimens were lacking across all included studies.

**Certainty in evidence**

GRADE was applied to the primary objective and indicated that the certainty in evidence was “low” to support the sole use of PT to alleviate symptomatic TR. This assessment was primarily made due to imprecision, as 5 out of the 7 included articles were case studies, and risk of bias, as 57% of the included studies were assessed as having less than “good” study quality. A summary of the GRADE criteria selection for each paper and the overall certainty in evidence is provided (Table 2).

**Meta-narrative of included studies**

Pirti et al. [13] conducted a prospective cohort study of 139 patients with non-cyclic breast pain. One hundred had normal breast and axillary examinations, negative mammography and/or negative ultrasounds. These 100 patients then received cervical and thoracic spine MRIs. Four patients had no pathologic findings, 96 had evident pathology. Of those with MRI-con-
firmed pathology, 49 had diffuse cervical-level annular bulging and 47 had cervical disc protrusions. Twelve of 47 also had a thoracic disc protrusion causing thoracic nerve root impingement. All 96 patients received PT that was not specifically described. The authors’ main outcome measure was post-intervention visual analogue scale (VAS). Average VAS at initial examination was 7.06. Seven patients were excluded due to non-compliance with PT. At month 3, 5.6% of patients showed mild-to-moderate improvement, 61.7% showed significant improvement, and 32.5% achieved complete pain remission. Average VAS at month 3 was 1.11. Data stratified by cervical vs. cervical and thoracic disc protrusion was not provided.
Brown et al. [3] performed a retrospective review of 55 patients with significant thoracic disc herniations causing nerve root impingement on thoracic spine MRI. Interviews were conducted to assess their clinical presentation, treatment, and return to activity. They found that 67% of patients experienced an early symptom of anterior band-like chest pain while muscle weakness was observed in 16%. Lesser common symptoms included interscapular pain (8%) and epigastric pain (4%). The operative group (27%) eventually underwent surgery. Over half of the patients who required surgery (55%) had disc herniation below the T9 level, whereas the non-operative group showed a higher frequency of disc herniation between T6–T9 (48%). Differences between the two groups in terms of disc hydration, degree of herniation, number of herniated discs, or level of herniation were not significant. The non-operative group sought treatments including rest, nonsteroidal anti-inflammatory medications, and PT regimens consisting of hyperextension strengthening, postural training, and proper body mechanics education. Duration of PT regimens were not specified. These 77% of patients in this group were able to return to their previous level of activity by the final follow-up visit. They concluded that patients can effectively manage symptomatic TR from disc herniations with rest, medication, and structured PT.

Fitzpatrick et al. [11] presented a case study of two male pa-
patients, ages 57 (patient 1) and 67 (patient 2), who developed thoracic, lumbar pain, muscle spasms, local abdominal swelling, and thoracic allodynia. Both had TR identified by thoracic spine MRI. The TR for patient 1 was caused by an extraforaminal disc protrusion while the TR for patient 2 was caused by foraminal and paramedian disc protrusion with concurrent facet joint arthropathy and small anterior osteophyte complex. Each completed a course of PT, which was not specifically described. Patient 1 experienced symptom resolution at month 8 while patient 2 experienced 90% symptom resolution at month 5.

Hurh and Rho [12] described a case study of a 65-year-old male who had a two-week history of radiating thoracic rib pain into his anterolateral chest wall and lateral abdominal muscle bulging. A thoracic spine MRI identified a T9 radiculopathy caused by T9–T10 lateral foraminal disc extrusion. He completed a course of PT with complete resolution of his pain and improvement in his abdominal bulge by month 6. The regimen of PT was not specifically described.

Kato et al. [16] reported a case study of two Japanese male professional baseball pitchers, ages 22 (patient 1) and 27 (patient 2), who developed chest and upper abdominal pain, as well as numbness. Thoracic spine MRI revealed TR caused by ossification of the ligamentum flavum. Each patient underwent a course of PT described as “manual therapy, postural re-education, and exercise therapy aimed at minimizing thoracic kyphosis-induced spinal loading by increasing the strength and endurance of the back extensors.” The pain and sensory symptoms gradually resolved. Patient 1 returned to play 6 weeks after onset; this patient did not have documented recurrence of symptoms. Patient 2 returned to exercise 2 weeks after initiation of PT and had symptom resolution by month 4. However, 7 years after the initial presentation he did experience symptom recurrence.

Sundar and Rho [14] presented a case study of a 33-year-old male with left-sided chest wall and left upper extremity paresthesia. Thoracic spine MRI revealed a left paracentral T3–T4 disc protrusion with superior migration which impinged the right half of the spinal cord causing a leftwards shift of the cord, resulting in a TR. The patient started McKenzie method PT with a focus on cervicothoracic extension-based exercises. His symptoms decreased by 70%–80% following 10 sessions.

Valentas et al. [15] presented a case study of a 48-year-old female who presented with radiating right flank pain to the abdomen and back. Gastrointestinal or respiratory etiology was ruled out. Thoracic spine MRI showed right T8–T9 neural foraminal narrowing and a T9 butterfly vertebra, causing a right T8 radiculopathy. She was started on nortriptyline, tizanidine and began a course of PT. The PT regimen was not specifically described. The patient’s symptoms had improved by month 6.

Overall, 74 patients were included in this systematic review. Seventy-one had symptoms produced by a thoracic disc protrusion, 2 by ossification of the ligamentum flavum, and 1 by a T9 butterfly vertebra causing neuroforaminal narrowing.

**DISCUSSION**

This systematic review analyzed the efficacy of participating in a structured, supervised PT program on symptomatic TR. Seven studies were included: 5 case studies, 1 prospective cohort study, and 1 retrospective cohort study. A total of 74 patients with TR were treated with PT prior to any advanced procedures. Although the level of evidence is poor, all studies showed improvement in or resolution of the TR symptoms.

The uncommon diagnosis of TR may elude physicians unfamiliar with its presentation, leading to misdiagnosis, unnecessary procedures, and increased healthcare costs [18]. Given the variability in presentation and etiology, it is essential for a clinician to thoroughly evaluate the patient before arriving at a diagnosis of TR. Diagnosing TR can be challenging due to the complex anatomy, limited procedural access to the thoracic spine, and overlap in symptoms with more common etiologies, such as cardiac, lung or gastroenterological pathologies [2,18].

To differentiate the pathologies, a careful history and physical examination may reveal paraspinal tenderness, dermatomal pain and sensory abnormalities, absent or asymmetric superficial abdominal reflexes, or bulging in the musculature of the affected side, also known as a pseudohernia. These findings can prompt consideration for obtaining MRI; however, specific clinical criteria for diagnosis have not been established [11]. MRI is valuable for assessing the etiology of anatomic compression of thoracic nerve roots or the presence of nerve root T2 hyperintensity in neural damage [1,2]. MRI can also identify the presence of myeloradiculopathy where both the nerve roots and spinal cord are involved. Prompt diagnosis is crucial as the presence of myelopathy can increase patient morbidity [1].

This systematic review highlights that TR presents as a dermatomal pattern of one or more symptoms, such as pain, paresthesia, allodynia, or numbness. This may manifest in the abdomen, flank, chest, back or even breast. Movement may exacerbate the symptoms. Many described an asymmetric abdom-
inal bulge or swelling, representing truncal muscle weakness. Thoracic spine MRI identified the TR in every case.

The most common radiculopathy is symptomatic lumbosacral radiculopathy (LSR) which is seen in 3%–5% of the population and 12%–40% of those experiencing low back pain [19]. A common conservative treatment algorithm for LSR includes patient education, physical activity, and structured PT. If conservative treatment fails, the next step is referral to a specialist to decide between an epidural steroid injection versus surgical decompression [20]. Between 70%–90% of patients improve by conservative treatment alone [21].

Less common is cervical radiculopathy (CR) which is seen in 0.35% of the population [22]. Recommendations for CR mirror those for LSR with the addition of therapeutic modalities, and cervical traction [22,23]. Like LSR, approximately 90% of patients improve by conservative treatment alone [22].

TR differs from its neighboring counterparts in part because of unique structural qualities. Unlike the cervical or lumbosacral spine, the thoracic spine is relatively immobile due to the costovertebral and sternocostal joints. Other unique characteristics include kyphosis, reduced intervertebral disc height and volume, increased spinal cord/canal ratio, and more tenuous vascular supply [1,18,21]. Damage to thoracic nerve roots may occur from degenerative changes in the thoracic vertebrae or intervertebral discs, direct compression from trauma or spinal tumors, inflammatory conditions, or even secondary to diabetic radiculoneuropathy. Anatomic and etiologic differences contribute to the determination of efficacious treatments; however, a formal recommendation based on these differences has not been made from the sparse available data. Expert consensus appears to favor a similar treatment algorithm to CR and LSR. Conservative treatments include PT, weight loss, and mindfulness [1,18]. Data is also sparse on more interventional treatments, such as epidural steroid injections or surgical decompression [24,25].

Limitations

TR appears to be a relatively rare—or at least rarely identified—condition, and this systematic review is limited by the relatively low number of studies (n=7) and included patients (n=74) as well as the fact that there were no randomized control trials found in the literature. These 71% of the studies included were 1–2 patient case studies. Most of the case study patients were male. Many of the studies lack thorough descriptions of the utilized PT programs, outcomes, follow-up periods, and therapy settings which makes replication and clinical applicability difficult. Since no studies included a control group and we excluded studies only if patients underwent advanced interventional procedures, it is difficult to know whether patient improvement was a direct result of PT or some other part of conservative treatment, such as time, rest, or oral medications. The types and length of PT regimens varied widely across the included studies. This review was limited to results in English; relevant studies in other languages may have been excluded. Finally, the inclusion criteria of requiring an MRI-confirmed TR may have been too stringent and excluded other pertinent symptomatic TR studies.

CONCLUSION

Per GRADE, there is low certainty in the evidence to support the use of PT as the sole conservative treatment for symptomatic TR with more than half of the studies (n=4) having less than “good” study quality. This review was limited by a paucity of studies (n=7), of which 71% were case studies. Additionally, few studies (n=3) detailed what PT protocol was used in treatment, making clinical applicability difficult. However, all studies reported pain or functional improvement following a regimen of PT for TR. From the limited number of included studies in this systematic review, conservative treatment led by a PT regimen may help to alleviate symptomatic TR. Further intervention controlled RCTs are needed to strengthen the current literature and establish the efficacy of PT as a conservative treatment for TR. This systematic review highlights the need to define the optimal interventions and the duration of PT treating of TR.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

FUNDING INFORMATION

None.

AUTHOR CONTRIBUTION

Conceptualization: Mostert KA, Buus RJ, Prideaux C. Methodology: Mostert KA, Meiling J, Gerberi D, Prideaux C. Formal analysis: Mostert KA, Perera J, Dens Higano J, Davis PT, Meiling J. Project administration: Mostert KA. Visualization:
Mostert KA, Meiling J. Writing – original draft: Mostert KA, Perera J, Dens Higano J, Davis PT. Writing – review and editing: Mostert KA, Meiling J, Buus RJ, Prideaux C. Approval of final manuscript: all authors.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found via https://doi.org/10.5535/arm.23136.

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REFERENCES


Association of Nutritional Risk With Gait Function and Activities of Daily Living in Older Adult Patients With Hip Fractures

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Objective: To investigate the association of nutritional risk with gait function and activities of daily living (ADLs) in older adult patients with hip fractures.

Methods: The retrospective data of older adult patients diagnosed with hip fractures who visited the recovery-phase rehabilitation ward between January 2019 and December 2022 were reviewed. Nutritional risk was evaluated using the Geriatric Nutritional Risk Index; gait function and ADLs were assessed using the modified Harris Hip Score subitem and Functional Independence Measure, respectively. Multivariate linear regression and path analysis with structural equation modeling were used to examine the factors associated with ADLs and the associations among the study variables.

Results: This study included 206 participants (172 females and 34 males; mean age, 85.0±7.3 years). In the multivariate analysis, gait function (β=0.488, p<0.001), cognitive function (β=0.430, p<0.001), and surgery (β=-0.143, p<0.001) were identified as independent factors. Pathway analysis revealed that nutritional risk was not directly correlated with ADLs but was directly associated with gait and cognitive functions. Gait and cognitive functions, in turn, were directly related to ADLs.

Conclusion: Nutritional risk was found to be associated with ADLs through an intermediary of gait and cognitive functions.

Keywords: Activities of daily living, Cognitive function, Gait, Hip fractures, Nutrition assessment

INTRODUCTION

Hip fractures are the most prevalent fracture among older adult patients, and their incidence is expected to increase [1,2]. Approximately 20%–40% of hospitalized older adult patients with hip fractures exhibit nutritional risk [3]. The effects of nutritional risk on clinical outcomes after hip fractures include increased mortality [4], complications during hospitalization such as infectious disease and delirium [5,6], and delayed functional recovery [7,8].

Recently, a growing body of literature has focused on the effect of nutritional risk on activities of daily living (ADLs) [9-12]. However, owing to the complex nature of ADLs comprising various factors [13], the influence of nutritional risk on ADLs...
remains controversial. Previous studies that demonstrated the association of nutritional risk with ADLs commonly used the Mini Nutritional Assessment (MNA) as a tool for nutritional screening [14]. Owing to the inclusion of functional assessments such as gait and cognitive function as subitems in the MNA, there exists a potential for an overestimation in the association between MNA and ADLs. Notably, while ADLs in patients with hip fractures exhibited an association with MNA, other established nutritional screening tools such as the Malnutrition Universal Screening Tool, Nutritional Risk Screening 2002, and the Geriatric Nutritional Risk Index (GNRI) did not demonstrate any such relationship [15]. Furthermore, when assessing the nutritional risk of older adult patients, there is a concern that MNA overestimates nutritional risk with high sensitivity and low specificity [16,17]. Consequently, older adult patients who are at nutritional risk based on the MNA may exhibit gait and cognitive function issues. Therefore, when attempting to elucidate the distinction between nutritional risk, gait function, and ADLs, the MNA is deemed unsuitable.

One of the nutritional indices for hospitalized older adult individuals is the GNRI, which is determined based on the serum albumin level and the ratio of current to ideal body weight. Its distinctive feature is its applicability to patients with cognitive impairment, and it can be easily measured using routine tests [18], making it a user-friendly tool for hip fracture patients. Previous studies evaluating the nutritional risk of patients with hip fractures using the GNRI have revealed its predictive value for postoperative survival rates [19]. However, the association of GNRI with gait function and ADLs has not been examined. Nutritional risk assessment using the GNRI may allow for elucidation of the influence of only nutritional risk on ADLs in older adult patients with hip fractures.

Determination of whether nutritional risk directly or indirectly affects ADLs through gait function can contribute to furthering the understanding of nutritional risk, gait function, and ADLs in hospitalized older adult patients with hip fractures, potentially supporting the development of effective physical therapy.

METHODS

Study design and participants
This retrospective observational study included patients discharged from the recovery phase rehabilitation ward of Nishio Hospital between January 2019 and December 2022. Inclusion criteria involved patients with hip fractures aged ≥65 years. Exclusion criteria included patients who died, those discharged because of deterioration in their condition by the onset of acute illnesses, or those who had missing data. In Japan, patients who cannot be discharged from acute care hospitals after acute hip fractures are admitted to a recovery phase rehabilitation ward for functional recovery. This policy was introduced in 2000 under Japan’s National Health Insurance system to provide ongoing rehabilitation in a hospital setting.

The study was conducted in accordance with the Declaration of Helsinki and the Strengthening the Reporting of Observational Studies in Epidemiology statements. This study was approved by the Bioethics Committee of Nagoya University (approval number: 23-512) and the Ethics Committee of Nishio Hospital (2023-001). Owing to the retrospective nature of this study, the requirement for informed consent was waived. Instead, participants were provided with the option to opt-out: information regarding the study was posted on the hospital notice board and the university’s webpage, allowing patients to withdraw their participation at any time.

Variables
Nutritional risk
This study used the GNRI as a nutritional risk indicator [18]. The formula for calculating GNRI is as follows:

\[ GNRI = (1.489 \times \text{serum albumin value}) + [41.7 \times \text{current weight (kg)}/\text{ideal weight (kg)}] \]

Calculation of ideal weight (Lorenz formula):

For male: Height (cm) - 100 - [(Height (cm) - 150)/4]
For female: Height (cm) - 100 - [(Height (cm) - 150)/2.5]

The GNRI calculations used the serum albumin level, height, and weight assessed upon admission to the rehabilitation ward.

Gait function
Gait function was assessed using the modified Harris Hip Score (mHHS) [20], a disease-specific instrument that assesses hip disabilities and is often used by healthcare workers to evaluate functional outcomes or interventions [21]. The mHHS comprises eight questions divided into subsections on pain, gait function, and ADLs. The pain subsection measures pain severity, its effect on activity, and the need for analgesics
Gait function subsection assesses limp, support needed, and distance walked (three items, 0–33 points), whereas the ADLs subsection evaluates managing shoes and socks, stairs, using public transportation, and sitting (four items, 0–14 points), with a total score of 91. A higher score indicated less pain and better gait function and ADLs.

The mHHS has been used to functionally evaluate patients for the total score and the score of each subsection \[22,23\]. The assessment was performed at discharge during the recovery phase in the rehabilitation ward. We did not use the mHHS ADLs subsections because ADLs performance was evaluated using the Functional Independence Measure (FIM) described below.

**ADLs performance**

ADLs performance was assessed using the FIM motor (FIM-M) items, with a hip fracture mobility subscale for assessing ADLs in patients with hip fractures \[24\]. The FIM-M items included 13 domains (eating, grooming, bathing, dressing the upper body, dressing the lower body, toileting, bladder management, bowel management, transfer to bed/chair/wheelchair, transfer to toilet, transfer to tub/shower, locomotion by walking or wheelchair, climbing stairs) and were scored from 1 (complete assistance) to 7 (complete independence), resulting in a total FIM-M score ranging from 13 to 91. The FIM-M was assessed upon discharge from the rehabilitation ward.

**Basic patient information and clinical characteristics**

Basic patient information included age, sex, body mass index (BMI), Mini-Mental State Examination (MMSE) score, prefracture walking status, and the number of days elapsed from injury to discharge at the rehabilitation hospital. Prefracture walking status was classified into independent walking, walking with a cane, walking with a walker, or using a wheelchair, in reference to the cumulative ambulation score \[24\]. The number of days elapsed was measured from the time of injury to admission to the rehabilitation ward and from admission to discharge from the rehabilitation wards.

Patient clinical characteristics included the updated Charlson comorbidity index (uCCI) score \[25\], hip fracture type (femoral neck or trochanteric), fracture side (right or left), surgical procedure (open reduction with internal fixation, hemiarthroplasty, or conservative), blood biochemistry data (serum albumin, total protein, and C-reactive protein), and polypharmacy. Polypharmacy was defined as six or more medications. Basic patient information and clinical characteristics, excluding the number of days elapsed, were assessed at the time of admission to the rehabilitation ward.

**Statistical analysis**

Patients were classified into four groups using GNRI criteria, ranging from no nutritional risk (>98), low (92–98), moderate (82–98), to major (<82) \[18\]. Patient characteristics were compared among groups using one-way ANOVA and the chi-square test for continuous variables and categorical variables, respectively.

The relationships between FIM-M and basic information, clinical characteristics, and nutritional indicators were evaluated. Continuous data were analyzed using Pearson’s correlation coefficient and Spearman’s correlation coefficient for categorical data. Additionally, surgical procedures (open reduction with internal fixation and hemiarthroplasty vs. conservative) and prefracture gait status (independent gait vs. walking with a cane, walker, and wheelchair) were categorized into two groups. The GNRI was included as a continuous variable. After correlation analysis, multiple regression analysis (stepwise method) was performed to investigate the factors influencing FIM-M. The independent variables were selected from previously studied factors \[13\] and variables with significant correlations.

Path analysis was used to elucidate the association between GNRI, FIM-M, gait function, and associated factors. This analysis enabled efficient and direct modeling and testing of indirect or mediated relationships among variables. Fig. 1 shows

**Fig. 1.** Hypothesized model. uCCI, updated Charlson comorbidity index; GNRI, Geriatric Nutritional Risk Index; MMSE, Mini-Mental State Examination; ADLs, activities of daily living.
A hypothetical model based on a previous study. Nutritional risk has been identified as a predictive factor for gait function [8] and ADLs [10,11] through cohort studies. Similarly, factors such as gait function have also been demonstrated as predictive factors for ADLs within the context of cohort studies [13]. The hypothesized model was refined based on the results of the correlation and multiple regression analyses, and path analysis was conducted to assess the model fit. All statistical analyses were performed using IBM SPSS software and Amos (version 26.0; IBM Corp.), with the significance level set at 5%.

Table 1. Basic patient information and clinical characteristics by the nutritional risk group

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n=206)</th>
<th>No risk (n=51)</th>
<th>Low risk (n=31)</th>
<th>Moderate risk (n=74)</th>
<th>Major risk (n=50)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>85.0±7.3</td>
<td>81.5±7.2</td>
<td>83.7±6.9</td>
<td>86.7±6.8</td>
<td>87.9±7.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex, female (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>83.5</td>
<td>78.4</td>
<td>90.3</td>
<td>85.1</td>
<td>82.0</td>
<td>0.527</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>19.8±3.6</td>
<td>24.1±3.2</td>
<td>20.9±2.1</td>
<td>18.5±2.6</td>
<td>16.7±2.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MMSE (p)</td>
<td>17.1±8.7</td>
<td>22.9±8.2</td>
<td>20.0±8.5</td>
<td>16.7±8.9</td>
<td>15.3±9.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prefracture walking status (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Independent walk</td>
<td>47.6</td>
<td>54.9</td>
<td>51.6</td>
<td>41.9</td>
<td>46.0</td>
<td></td>
</tr>
<tr>
<td>With cane</td>
<td>16.5</td>
<td>13.7</td>
<td>16.1</td>
<td>24.3</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>With walker</td>
<td>28.6</td>
<td>27.5</td>
<td>25.8</td>
<td>25.7</td>
<td>36.0</td>
<td></td>
</tr>
<tr>
<td>With wheelchair</td>
<td>7.3</td>
<td>3.9</td>
<td>6.5</td>
<td>8.1</td>
<td>10.0</td>
<td>0.431</td>
</tr>
<tr>
<td>Number of days elapsed (day)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From injury to admission to</td>
<td>32.4±20.0</td>
<td>32.2±15.3</td>
<td>29.2±13.7</td>
<td>30.8±21.6</td>
<td>37.1±24.4</td>
<td>0.255</td>
</tr>
<tr>
<td>rehabilitation hospital</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From admission to discharge at</td>
<td>70.6±22.1</td>
<td>66.0±22.3</td>
<td>68.1±26.3</td>
<td>71.4±22.1</td>
<td>76.0±18.3</td>
<td>0.125</td>
</tr>
<tr>
<td>rehabilitation hospital</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>uCCI (p)</td>
<td>1.6±1.4</td>
<td>1.3±1.4</td>
<td>1.6±1.4</td>
<td>1.7±1.4</td>
<td>2.2±1.6</td>
<td>0.024</td>
</tr>
<tr>
<td>Type of fracture (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Femoral neck</td>
<td>47.5</td>
<td>52.9</td>
<td>32.3</td>
<td>46.0</td>
<td>54.0</td>
<td></td>
</tr>
<tr>
<td>Trochanteric</td>
<td>52.5</td>
<td>47.1</td>
<td>67.7</td>
<td>54.0</td>
<td>46.0</td>
<td>0.220</td>
</tr>
<tr>
<td>Fracture side, right (%)</td>
<td>43.6</td>
<td>52.9</td>
<td>45.2</td>
<td>39.2</td>
<td>40.0</td>
<td>0.442</td>
</tr>
<tr>
<td>Surgical procedure (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open reduction with internal</td>
<td>48.6</td>
<td>56.9</td>
<td>54.8</td>
<td>50.0</td>
<td>34.0</td>
<td></td>
</tr>
<tr>
<td>fixation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemiarthroplasty</td>
<td>22.3</td>
<td>23.5</td>
<td>19.4</td>
<td>20.3</td>
<td>26.0</td>
<td></td>
</tr>
<tr>
<td>Conservative</td>
<td>29.1</td>
<td>19.6</td>
<td>25.8</td>
<td>29.7</td>
<td>40.0</td>
<td>0.274</td>
</tr>
<tr>
<td>Albumin (g/dL)</td>
<td>3.5±0.4</td>
<td>3.9±0.2</td>
<td>3.8±0.3</td>
<td>3.5±0.3</td>
<td>3.0±0.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total protein (g/dL)</td>
<td>6.7±0.6</td>
<td>7.1±0.6</td>
<td>7.0±0.6</td>
<td>6.8±0.5</td>
<td>6.2±0.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>C-reactive protein (mg/dL)</td>
<td>1.1±2.0</td>
<td>1.1±2.7</td>
<td>0.7±1.2</td>
<td>1.2±1.8</td>
<td>1.3±2.1</td>
<td>0.667</td>
</tr>
<tr>
<td>Polypharmacy (%)</td>
<td>46.6</td>
<td>60.8</td>
<td>45.2</td>
<td>43.2</td>
<td>38.0</td>
<td>0.113</td>
</tr>
<tr>
<td>mHHS (p)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>36.5±9.0</td>
<td>38.5±7.9</td>
<td>35.6±19.9</td>
<td>36.8±9.3</td>
<td>34.6±8.8</td>
<td>0.163</td>
</tr>
<tr>
<td>Gait function</td>
<td>10.1±9.9</td>
<td>15.3±10.4</td>
<td>11.8±10.1</td>
<td>9.0±9.3</td>
<td>5.7±7.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FIM-M</td>
<td>52.3±24.6</td>
<td>64.4±25.7</td>
<td>55.4±23.4</td>
<td>48.7±23.1</td>
<td>43.2±21.5</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.
Statistical test: ANOVA for age, body mass index, MMSE, uCCI, albumin, total protein, C-reactive protein, number of days elapsed, mHHS, FIM-M; Pearson's chi-square test for sex, fracture type, fracture side, surgical procedure, and prefracture walking status.
MMSE, Mini-Mental State Examination; uCCI, updated Charlson Comorbidity Index; mHHS, modified Harris Hip Score; FIM-M, Functional Independence Measure motor.
RESULTS

In total, 228 older adult patients with hip fractures were discharged from the recovery-phase rehabilitation ward. Among these, 7 died during hospitalization, 12 were discharged because of deterioration in their condition, and 3 had missing data. The final analysis included 206 patients (Fig. 2).

Basic information and clinical characteristics of the total patient cohort and of the four nutritional risk groups are shown in Table 1. Of the 206 patients, 172 (83.5%) were females and 34 (16.5%) were males. The mean age was 85.0±7.3 years and the MMSE score was 17.1±8.7 points. Among the patients, 98 (47.6%) had femoral neck fractures and 108 (52.4%) had trochanteric femoral fractures. The mean mHHS pain score was 36.5±9.0 points, and the mean gait function score was 10.1±9.9 points. The mean mMHS was 36.5±9.0 points, and the mean gait function score was 10.1±9.9 points. The mean FIM-M score was 52.3±24.6 points. The GNRI assessment indicated that 51 patients (24.8%) had no nutritional risk, 31 (15.0%) had low risk, 74 (35.9%) had moderate risk, and 50 (24.3%) had major risk. The mean GNRI was 89.5±10.5. Patients with no nutritional risk were significantly younger and had higher MMSE, gait function (mHHS), and FIM-M scores (p<0.001).

Table 2 shows the results of the correlation analysis between ADLs (FIM-M), basic information, clinical characteristics, and the GNRI. ADLs (FIM-M) was significantly correlated with age, BMI, MMSE, prefracture walking status, uCCI, surgical procedure, albumin level, C-reactive protein level, mHHS (pain and gait function), and GNRI score. Table 3 shows the results of the multiple regression analysis of ADLs (FIM-M). Multiple regression analysis was performed using age and number of days elapsed as adjustment factors and significant items in the correlation analysis as independent variables (MMSE, prefracture walking status, uCCI, surgical procedure, albumin level, C-reactive protein level, mHHS (pain and gait function), and GNRI). The independent factors for ADLs (FIM-M) were gait function, MMSE score, and surgical procedure. The model explained 78.1% of the variance (adjusted R²) in ADLs (FIM-M).

Fig. 3 depicts the path analysis results. Based on the results of the multiple regression analysis, only significant paths were retained, and other significant factors were added. The final path model was an excellent fit for data (χ²=12.825, p=0.234, GFI=0.985, AGFI=0.946, CFI=0.996, RMSEA=0.037). The following significant correlations were identified: Nutritional risk (standardized estimate=0.13) and cognitive function (standardized estimate=0.36) were associated with gait. Gait function (standardized estimate=0.48) and cognitive function (standardized estimate=0.43) were related to ADLs, whereas nutritional risk was not. Furthermore, nutritional risk was associated with cognitive function (standardized estimate=0.32) and comorbidities (standardized estimate=−0.21).

Table 2. Correlation between ADLs and other variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADLs (FIM-M)</th>
<th>Coefficient (r)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.459</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>0.093</td>
<td>0.181</td>
<td></td>
</tr>
<tr>
<td>Body mass index</td>
<td>0.280</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>0.749</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Prefracture walking status</td>
<td>0.333</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Number of days elapsed</td>
<td>0.26</td>
<td>0.121</td>
<td></td>
</tr>
<tr>
<td>From injury to admission to rehabilitation hospital</td>
<td>0.076</td>
<td>0.712</td>
<td></td>
</tr>
<tr>
<td>From admission to discharge at rehabilitation hospital</td>
<td>0.091</td>
<td>0.192</td>
<td></td>
</tr>
<tr>
<td>uCCI</td>
<td>-0.456</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Fracture type</td>
<td>-0.052</td>
<td>0.457</td>
<td></td>
</tr>
<tr>
<td>Fracture side</td>
<td>-0.108</td>
<td>0.121</td>
<td></td>
</tr>
<tr>
<td>Surgical procedure</td>
<td>-0.534</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Albumin</td>
<td>0.261</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Total protein</td>
<td>0.044</td>
<td>0.532</td>
<td></td>
</tr>
<tr>
<td>C-reactive protein</td>
<td>-0.209</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Polypharmacy</td>
<td>0.019</td>
<td>0.782</td>
<td></td>
</tr>
<tr>
<td>mHHS (p)</td>
<td>-0.143</td>
<td>-0.12.545</td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>0.423</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Gait function</td>
<td>0.822</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>GNRI</td>
<td>0.340</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

Statistical test: Pearson’s correlation coefficient for age, body mass index, MMSE, uCCI, albumin, total protein, C-reactive protein, number of days elapsed, and GNRI; Spearman’s rank correlation coefficient for sex, fracture type, fracture side, surgical procedure, and prefracture walking status.

ADLs: activities of daily living; FIM-M: Functional Independence Measure motor; MMSE: Mini-Mental State Examination; uCCI, updated Charlson Comorbidity Index; mHHS: modified Harris Hip Score; GNRI, Geriatric Nutritional Risk Index.

Table 3. Multiple regression analysis results of the variable that affected ADLs

<table>
<thead>
<tr>
<th>p-value</th>
<th>β</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait function</td>
<td>&lt;0.001</td>
<td>0.488</td>
<td>0.952</td>
</tr>
<tr>
<td>MMSE</td>
<td>&lt;0.001</td>
<td>0.430</td>
<td>0.963</td>
</tr>
<tr>
<td>Surgical procedure</td>
<td>&lt;0.001</td>
<td>-0.143</td>
<td>-12.545</td>
</tr>
</tbody>
</table>

ADLs: p<0.001, adjusted R²=0.781.
ADLs, activities of daily living; MMSE, Mini-Mental State Examination; 95% CI, 95% confidence interval.
DISCUSSION

The results of this study indicate that nutritional risk was associated with ADLs through gait function in older adult patients with hip fractures. Using path analysis, we traced the complex pathways through which nutritional risk is correlated with gait function and ADLs. The final path analysis model revealed that nutritional risk was directly related to gait function but was not directly associated with ADLs, whereas gait function was directly related to ADLs.

This study revealed that nutritional risk was not directly associated with ADLs, which is inconsistent with the findings of previous research. Most studies that have concluded an independent association between nutritional risk and ADLs have used the MNA to assess nutritional status \[9-12\]. The utilization of the MNA, including gait function, in nutritional risk assessment might be the causal factor directly related to ADLs. Gait function was the factor most highly correlated with ADLs in the standardized regression coefficients of the path analysis in this study. Furthermore, cognitive function emerged as a variable directly correlated to ADLs following gait function. Therefore, nutritional risk may be associated with ADLs via the intermediary of gait and cognitive functions. The MNA is a comprehensive nutritional risk indicator that has excellent relevance to other assessments, including prognosis prediction of ADLs. In contrast, the GNRI used in this study allowed for the structural separation of nutritional risk, gait function, cognitive function, and ADLs. This feature enabled a clear delineation of each issue.

The association of nutritional risk with ADLs through the intermediary factors of gait and cognitive function among patients with hip fractures can be described with reference to the recovery process specific to this patient group. This recovery process comprises a sequence initiated by pathology leading to impairment, followed by hip fracture repair and healing, in which nutritional risk plays a role in recovery from impairment. Subsequently, recovery from functional limitations, encompassing gait and cognitive function, is achieved, culminating in recovery from disability, including ADLs \[26\]. Considering the temporal sequencing of the recovery process and the relationship between nutritional status, gait and cognitive functions, and ADLs in patients with hip fractures \[13\], the path analysis in this study reveals the delineation of such a relationship from nutritional risk through gait and cognitive function, leading to ADLs. Additionally, we clarified the association between nutritional risk on ADLs and gait function in a path analysis that incorporated prefracture walking status, surgical procedures, and comorbidities, which were factors affecting ADLs in previous studies. Our findings will be useful for rehabilitation programs.
that consider the nutritional risks of older adult patients with hip fractures.

Based on the findings of this and previous studies, the rationale behind the association with nutritional risk on ADLs through gait function is as follows. The relationship between nutritional risk and gait should be considered in frailty and sarcopenia cases. There is a consensus that malnutrition in older adults is associated with frailty and sarcopenia [27], and the malnourished status of patients with hip fractures causes frailty [28] and sarcopenia [29]. The diagnostic criteria for frailty and sarcopenia include a decline in gait function [30,31], making it evident that a close relationship exists between these conditions and gait function. Frailty and sarcopenia affect gait function in patients with hip fractures [32,33]. Therefore, frailty and sarcopenia arising from malnutrition may affect gait function. However, regarding the relationship between nutritional risk and cognitive function, the intricate mechanisms underlying the effect of malnutrition on cognitive function have not been fully elucidated. Nevertheless, clinical evidence has shown many instances linking malnutrition to cognitive function [34,35]. Furthermore, malnutrition in patients with hip fractures results in a more pronounced decline in ADLs when combined with cognitive impairment [12]. Although we were unable to collect indicators related to the skeletal muscle in this study, it is reasonable to assume that the skeletal muscle is a mediating factor between nutritional risk and gait function based on previous research. Future studies should address this issue to elucidate the interrelationships among the nutritional risk, skeletal muscle, and ambulatory function.

This study had some limitations. Path analysis could not establish causal relationships because of the study’s retrospective nature. A prospective research design was essential to explore the temporal relationships between the variables included in this study. Additionally, as the study was conducted at a single institution, there is a potential for selection bias. Notably, the serum albumin included in the GNRI is affected not only by nutritional risk but also by inflammatory states [36].

Despite these limitations, to our knowledge, this study is the first to investigate the relationship among nutritional risk, gait function, and ADLs in older adult patients with hip fractures. The results of this study support the importance of the relationship between nutritional status and gait function in multidisciplinary rehabilitation to improve ADLs in older patients with hip fractures [37].

In conclusion, nutritional risk was associated with ADLs through an intermediary of gait and cognitive functions. This study suggests that older adult patients with hip fractures who exhibit favorable nutritional status and good gait function may experience improved ADLs outcomes.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

FUNDING INFORMATION

None.

AUTHOR CONTRIBUTION

Conceptualization: Ishikawa Y, Adachi T, Uchiyama Y. Methodology: Ishikawa Y, Adachi T, Uchiyama Y. Formal analysis: Ishikawa Y. Project administration: Uchiyama Y. Writing – original draft: Ishikawa Y. Writing – review and editing: Adachi T, Uchiyama Y. Approval of the final manuscript: all authors.

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REFERENCES


Pract 2023;38:1063-72.


INTRODUCTION

Neck pain is a multifactorial disease and ranks among the most common musculoskeletal disorders, with an age-standardized prevalence rate of 2.7% globally in 2019 [1]. While many acute episodes resolve spontaneously, approximately one in five individuals affected by neck pain seek treatment within a year [2]. Chronic neck pain (CNP) imposes a substantial personal and socioeconomic burden, causing millions of years of life lost due to disability [3]. Given these adverse impacts on individuals affected by CNP, it is imperative that this condition be formally diagnosed and appropriately treated. Consequently, CNP warrants recognition as a distinct ailment, similar to other musculoskeletal disorders such as chronic low back pain [4].
The association between CNP and postural deviations, particularly forward head posture, in the adult population is well established [5]. Additionally, there has been a recent increase in CNP prevalence attributed to prolonged periods of neck flexion resulting from increased time spent viewing digital devices connected to the internet (DDCI) screens [6-8]. However, the relationship between CNP and DDCI usage is complex. Existing evidence has primarily stemmed from studies involving university students and a younger demographic, with some results showing an association [9-11] and others contradicting it [12-14]. These discrepancies can be attributed to the diversity of study methodologies used to define CNP and the selection of young participants through convenience sampling, contributing to study heterogeneity.

During the lockdown and social distancing measures implemented amidst the coronavirus disease 2019 (COVID-19) pandemic, the utilization of DDCI, such as smartphones, desktop computers, laptops, and tablets, increased due to the popularization of remote work, education, entertainment, and social interaction [15,16]. Particularly, Peru declared a state of emergency in March 2020, leading to the implementation of social distancing measures, including quarantine [17]. A study reported that approximately 76.2% of households in Peru had internet access, and nearly 90% of the population aged 12 and above used smartphones to browse the internet in 2019 [18]. This pre-pandemic landscape may have exacerbated the adverse effects of the COVID-19 lockdown on the population’s health and quality of life [19], potentially leading to increased neck problems, especially in Peru, where a survey conducted in 2016 estimated a CNP prevalence of 20.9% among a representative sample of adults [20]. Globally, the extent to which the frequency of CNP has changed following the relaxation of social restrictions remains unknown. With the lifting of restrictions in Peru in October 2022 [21], the absence of such evidence is a cause for concern. We hypothesized that the prevalence of CNP, defined herein as neck pain occurring daily or almost daily or at least once a week within the last 6 months, has increased following the lifting of COVID-19 restrictions compared with its pre-pandemic levels, primarily due to the increased usage of DDCI.

This study aimed to estimate the prevalence of CNP during the transition back to normalcy after COVID-19 restrictions in Peru and compare it with its prevalence during the pre-pandemic period. In addition, we evaluated the association between DDCI screen viewing and the occurrence of CNP.

METHODS

Ethical approval
This study was conducted in accordance with the principles of the Declaration of Helsinki, and the study protocol was approved by an Institutional Committee on Ethics in Research of Universidad de Piura (Act No. 14/2022). All participants were asked for informed consent. Statistical analyses were performed using an anonymized database and reported according to the STROBE guidelines.

Study design
This analytical, cross-sectional study was conducted in the Republic of Peru, a Latin American country divided administratively into 25 territories (grouped into five regions: Lima, North, Center, South, and East). The survey was population-based and conducted between November 24 and 25, 2022. The target population included individuals aged >18 years living in urban and rural areas. According to official data, the population size in 2021 was 24,290,921 individuals (50.2% females), with 79.9% residing in urban areas [22].

Sampling design
The sampling design was computed with a margin of error of 2.83%, a maximum variance of population proportions (p=0.50), and a 95% confidence interval (95% CI), resulting in a calculated sample size of 1,202 individuals. We employed a multistage sampling method. The first stage consisted of a probabilistic sample selection of locations via systematic random sampling, proportional to the number of inhabitants in each location. The second stage involved systematic sampling, with random selection of blocks of houses, where the probability of block selection was proportional to the number of houses. The third stage comprised the selection of houses through systematic sampling, with a random starting point. Finally, in the fourth stage, individuals within each household were selected based on their sex and age, to achieve the required distribution.

To perform the first, second, and third sampling stages, the cartography of the Instituto Nacional de Estadística e Informática del Peru generated during the national census of 2017 was utilized as the sampling frame [23].

Definition of variables
The variable of interest, CNP, was measured using two questions, each targeting different intervals. The first question in-
required: “Considering the last 6 months, have you experienced any pain in the neck, nape, or in the tops of your shoulders?” The second question evaluated a similar occurrence preceding the onset of the pandemic: “Did you experience any persistent pain in the neck, nape, or on the tops of your shoulders before March 2020 (prior to the COVID-19 lockdown) persistently, that is, lasting 6 months or more?”

For both questions, respondents were presented with five response options: (1) “Yes, I experienced pain in that area once a month on average;” (2) “Yes, I experienced pain in that area once a week on average;” (3) “Yes, I experienced pain in that area daily or almost daily;” (4) “No, I have not experienced any pain in that area;” and (5) “I could not tell.” Participants who responded to categories 2 and 3 were considered CNP cases.

The exposure variable was the number of hours spent viewing DDCI screens, measured through a third question: “On average, how many hours a day do you spend looking at a screen of a device connected to the internet, such as your cellphone (smartphone), laptop, personal computer, or tablet for study, work, or entertainment purposes?” Respondents were provided with the following response categories: (1) “I do not look at any screen, or I barely do it;” (2) “I spend <4 h/day looking at a screen;” (3) “I spend between 4 and 8 h/day looking at a screen;” (4) “I spend ≥8 h/day;” and (5) “I could not tell.”

The covariates were demographic characteristics, including age (years), sex, and household socioeconomic level (from “A” indicating higher resources to “E” indicating fewer resources). This socioeconomic variable was derived from the income of the household head, goods and services accessed, household appliances, and access to public services, as previously described. Other covariates included were resident area (urban, rural) and region (Lima, North, Central, South, and East).

Survey
Fieldwork was conducted by IPSOS Opinión y Mercados S.A. organization through face-to-face surveys conducted in the selected households. Data were collected by local resident interviewers who have experience in survey applications. Before administering the survey, the interviewer requested each participant’s consent. In instances where the selected participant was not at home, three additional visits were made. However, if the participants could not be reached after these attempts, they were replaced with individuals matching their age and sex characteristics.

Data collection was facilitated through mobile devices using the iField application (IPSOS Group S.A.), an integrated computer-aided personal interview platform. This approach enabled efficient location tracking of interviewers and participants during the survey, real-time quality control of data, reduced errors in data collection, closed card sorting, and ensured adherence to the sample selection process in assigning households.

Statistical analysis
An exploratory analysis confirmed the absence of data loss; thus, we analyzed the complete dataset. Continuous variables are presented using the mean and 95% CI. Categorical variables are expressed as weighted proportions. Additionally, unweighted absolute frequencies were provided, considering that the weights applied enable the expansion of frequencies to estimate the absolute parameter. The weighted proportions provided corrected and valid percentages representative of the population ≥18 years residing in Peru in November 2022.

The prevalence of CNP was estimated along with the corresponding 95% CI for two-time points: before the COVID-19 pandemic and during the return to normalcy (COVID-19 post-restrictions period). For this analysis, the primary outcome was CNP, defined as occurring daily or almost daily (response category 3) or at least once weekly (response category 2) onset. These frequency levels were selected for prevalence estimation, consistent with previous studies [24,25]. Prevalence was calculated by considering the total of participants in the survey as the denominator.

To estimate the dynamics of CNP changes before and after COVID-19 social restrictions, we utilized a contingency table, with CNP categories before restrictions forming the rows and categories for the post-restriction period forming the columns. Changes were depicted as weighted proportions. These prevalences were compared using McNemar’s test.

To evaluate the association between CNP and DDCI screen use, we considered CNP occurrence after COVID-19 social restrictions. Pearson’s chi-square test with a second-order Rao-Scott correction was used to compare the CNP proportions across strata defined by the study variables. This analysis was conducted among a subpopulation of participants who provided valid responses to the questions, excluding those who responded, “I could not tell.” Additionally, factors associated with DDCI screen-viewing were also identified. A subpopulation of participants with valid responses to this question was
used for analysis. At this stage, a statistical criterion (p<0.20) was applied to define the variables included in the regression model.

Ordinal logistic regression was employed to evaluate the association between DDCI screen-viewing and CNP. This model was chosen because CNP, the dependent variable, was measured using categories that reflected an order of frequency (i.e., no pain, daily or almost daily pain, weekly pain, and monthly pain). Prior to fitting the model, we evaluated whether the included variables met the proportional odds assumption by conducting the Wald test for parallel lines. A significance level >0.05 implied that the odds were proportional. This analysis was conducted independently for each variable and set of model variables. IBM SPSS Statistics version 25.0 (IBM Corp.) was used to verify these assumptions.

In the multivariate analysis, we formulated a complete model with all covariates at p<0.20. Additionally, socioeconomic status was included as an epidemiological criterion. Subsequently, a second (reduced) model was constructed, incorporating factors that were significant in the first multivariate model alongside the exposure of interest. Adjusted odds ratios (ORs), their corresponding 95% confidence intervals (95% CIs), and the estimated coefficient were presented for both models. McFadden and Nagelkerke’s pseudo-R-squared values were estimated to assess the global goodness-of-fit. Post-hoc statistical power calculations for the regression model were performed, considering factors such as the sample size, the number of predictors included in the models, the observed R-squared value, and a significance level of 5%.

Statistical analysis was performed for a complex survey sample using the svy command in Stata Statistical Software (Release 16; StataCorp LLC). Statistical significance was set at p<0.05.

RESULTS

A total of 1,202 participants (52.8% females) were included in this study. The mean age was 39.48 years (range, 18–85 years). Among them, 55.5% were within the age range of 30–60 years, 34.5% lived in Lima, and 79.9% lived in urban areas (Table 1).

Changes in the prevalence of CNP

During the return to normalcy, the prevalence of daily or almost daily CNP was 14.8% (95% CI, 12.6–17.3), while the prev-

<table>
<thead>
<tr>
<th>Variate</th>
<th>Unweighted count</th>
<th>Weighted proportion</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1,202</td>
<td>39.48 (38.49–40.47)</td>
<td>0.5</td>
</tr>
<tr>
<td>Age group (yr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 to &lt;30</td>
<td>384</td>
<td>31.6 (28.4–34.9)</td>
<td>1.7</td>
</tr>
<tr>
<td>30 to &lt;60</td>
<td>660</td>
<td>55.5 (52.0–58.8)</td>
<td>1.7</td>
</tr>
<tr>
<td>≥60</td>
<td>158</td>
<td>13.0 (10.9–15.3)</td>
<td>1.1</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>604</td>
<td>47.2 (43.8–50.6)</td>
<td>1.7</td>
</tr>
<tr>
<td>Female</td>
<td>598</td>
<td>52.8 (49.4–56.2)</td>
<td>1.7</td>
</tr>
<tr>
<td>Area of residence</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>1,001</td>
<td>79.9 (76.5–83.0)</td>
<td>1.7</td>
</tr>
<tr>
<td>Rural</td>
<td>201</td>
<td>20.1 (17.0–23.5)</td>
<td>1.7</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lima</td>
<td>500</td>
<td>34.5 (31.7–37.5)</td>
<td>1.5</td>
</tr>
<tr>
<td>North</td>
<td>270</td>
<td>23.8 (20.8–26.9)</td>
<td>1.6</td>
</tr>
<tr>
<td>Center</td>
<td>131</td>
<td>12.5 (10.2–15.2)</td>
<td>1.3</td>
</tr>
<tr>
<td>South</td>
<td>176</td>
<td>17.1 (14.3–20.3)</td>
<td>1.5</td>
</tr>
<tr>
<td>East</td>
<td>125</td>
<td>12.1 (10.1–14.5)</td>
<td>1.1</td>
</tr>
<tr>
<td>Socioeconomic level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>42</td>
<td>2.1 (1.6–2.9)</td>
<td>0.3</td>
</tr>
<tr>
<td>B</td>
<td>236</td>
<td>12.2 (10.2–14.6)</td>
<td>1.1</td>
</tr>
<tr>
<td>C</td>
<td>432</td>
<td>31.7 (28.8–34.6)</td>
<td>1.5</td>
</tr>
<tr>
<td>D</td>
<td>249</td>
<td>24.3 (21.4–27.4)</td>
<td>1.5</td>
</tr>
<tr>
<td>E</td>
<td>243</td>
<td>29.7 (26.4–33.3)</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Values are presented as number only or proportion (95% confidence interval).
The prevalence of CNP occurring at least once a week was 27.8% (95% CI, 24.9–30.9). These findings represented a significant increase compared to the estimates before the restrictions for both outcomes (McNemar’s test, p < 0.001).

Post-restriction, the prevalence of daily or almost daily CNP was 2.43 times higher than before the COVID-19 pandemic (95% CI, 1.78–3.08). Similarly, the prevalence of CNP occurring at least once a week increased by 2.25 times (95% CI, 1.86–2.64). Additionally, we estimated the difference in the weighted prevalence between the return to normal and before the restrictions for each population stratum (Table 2).

Among participants who did not experience any pain or had pain very rarely before the restrictions, 60.7% remained painless during the return to normal. For those who reported pain once a month before the restrictions, 17.0% and 12.3% reported an increase in frequency to once a week and daily or almost daily pain, respectively, during the return to normalcy. Additionally, among participants who experienced daily or almost daily pain before the restrictions, 45.9% remained at the same frequency of pain during the return to normal (Table 3).

### Table 2. Prevalence of daily chronic neck pain daily or almost daily, and at least once a week on average for the sample and according to strata

<table>
<thead>
<tr>
<th>Variate</th>
<th>Neck pain daily, or almost daily</th>
<th>Neck pain at least once a week on average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before COVID-19 pandemic</td>
<td>Return to normal</td>
</tr>
<tr>
<td>Global</td>
<td>6.1 (4.8–7.8)</td>
<td>14.8 (12.6–17.3)</td>
</tr>
<tr>
<td>Age group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 to &lt;30</td>
<td>5.0 (2.9–8.6)</td>
<td>8.5 (5.8–12.1)</td>
</tr>
<tr>
<td>30 to &lt;60</td>
<td>6.1 (4.5–8.2)</td>
<td>16.9 (13.7–20.6)</td>
</tr>
<tr>
<td>≥60</td>
<td>8.6 (4.8–15.0)</td>
<td>21.2 (15.0–29.2)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>5.4 (3.7–7.8)</td>
<td>9.6 (7.3–12.6)</td>
</tr>
<tr>
<td>Female</td>
<td>6.7 (4.8–9.2)</td>
<td>19.4 (15.9–23.5)</td>
</tr>
<tr>
<td>Area of residence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>6.2 (4.9–8.0)</td>
<td>14.4 (12.2–17.0)</td>
</tr>
<tr>
<td>Rural</td>
<td>5.4 (2.5–11.4)</td>
<td>16.2 (10.3–24.6)</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lima</td>
<td>7.9 (5.8–10.7)</td>
<td>16.1 (13.0–19.7)</td>
</tr>
<tr>
<td>North</td>
<td>6.0 (3.4–10.6)</td>
<td>17.8 (12.6–24.5)</td>
</tr>
<tr>
<td>Center</td>
<td>5.1 (2.3–11.0)</td>
<td>14.4 (8.6–23.1)</td>
</tr>
<tr>
<td>South</td>
<td>2.2 (0.9–5.3)</td>
<td>9.4 (5.3–16.2)</td>
</tr>
<tr>
<td>East</td>
<td>7.6 (3.7–14.9)</td>
<td>13.2 (7.9–21.3)</td>
</tr>
<tr>
<td>Socioeconomic level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>2.3 (0.3–14.6)</td>
<td>10.1 (3.8–24.1)</td>
</tr>
<tr>
<td>B</td>
<td>3.5 (1.7–6.9)</td>
<td>9.2 (5.9–14.0)</td>
</tr>
<tr>
<td>C</td>
<td>7.1 (4.9–10.1)</td>
<td>14.5 (11.3–18.4)</td>
</tr>
<tr>
<td>D</td>
<td>7.2 (4.6–11.1)</td>
<td>15.8 (11.6–21.1)</td>
</tr>
<tr>
<td>E</td>
<td>5.5 (3.1–9.6)</td>
<td>16.9 (12.0–23.3)</td>
</tr>
</tbody>
</table>

Values are presented as weighted proportion (95% confidence interval). COVID-19, coronavirus disease 2019; Δ, difference in proportions.
### Table 3. Changes in the recurrence of chronic neck pain before COVID-19 pandemic and during the return to normality

| Chronic neck pain before COVID-19 pandemic (%) | Neck pain during return to normality (%) | | | |
|-----------------------------------------------|----------------------------------------|---|---|---|---|---|
| No pain                                       | No pain                                | Once a month | Once a week | Daily, or almost daily | I could not tell |
| No pain                                       | 60.7<sup>a</sup>                       | 17.0<sup>b</sup> | 10.4<sup>c</sup> | 11.5<sup>c</sup> | 0.5 |
| Once a month                                  | 12.7<sup>a</sup>                       | 56.7<sup>b</sup> | 17.0<sup>c</sup> | 12.3<sup>c</sup> | 1.3 |
| Once a week                                   | 19.1<sup>a</sup>                       | 16.2<sup>c</sup> | 31.0<sup>c</sup> | 33.8<sup>c</sup> | 0   |
| Daily, or almost daily                        | 18.3<sup>a</sup>                       | 14.9<sup>c</sup> | 20.9<sup>c</sup> | 45.9<sup>c</sup> | 0   |
| I could not tell                              | 38.6                                   | 38.5          | 10.6          | 0              | 12.3 |

The cells show the weighted proportions for the rows. The total for the rows is 100%
<sup>a</sup>A positive change respect the frequency of chronic neck pain (CNP) or maintain free of CNP.
<sup>b</sup>CNP in the same frequency.
<sup>c</sup>A negative change.

### Table 4. Crude analysis of associated factors with chronic neck pain during the return to normality in adults of Peru

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>No pain</th>
<th>Once a month</th>
<th>Once a week</th>
<th>Daily, or almost daily</th>
<th>p-value&lt;sup&gt;ii&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1,188</td>
<td>607 (50.5)</td>
<td>252 (21.6)</td>
<td>161 (13.1)</td>
<td>168 (14.9)</td>
<td>-</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>598</td>
<td>352 (60.4)</td>
<td>120 (19.2)</td>
<td>69 (10.6)</td>
<td>57 (9.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Female</td>
<td>590</td>
<td>255 (41.5)</td>
<td>132 (23.6)</td>
<td>92 (15.3)</td>
<td>111 (19.6)</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 to &lt;30</td>
<td>381</td>
<td>216 (54.7)</td>
<td>71 (22.8)</td>
<td>59 (14.0)</td>
<td>35 (8.5)</td>
<td>0.039</td>
</tr>
<tr>
<td>30 to &lt;60</td>
<td>649</td>
<td>314 (49.3)</td>
<td>147 (20.7)</td>
<td>86 (12.9)</td>
<td>102 (17.0)</td>
<td></td>
</tr>
<tr>
<td>≥60</td>
<td>158</td>
<td>77 (45.3)</td>
<td>34 (22.1)</td>
<td>16 (11.4)</td>
<td>31 (21.2)</td>
<td></td>
</tr>
<tr>
<td>Urban Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>196</td>
<td>104 (54.7)</td>
<td>35 (18.8)</td>
<td>28 (10.2)</td>
<td>29 (16.4)</td>
<td></td>
</tr>
<tr>
<td>Lima</td>
<td>495</td>
<td>242 (48.7)</td>
<td>116 (22.7)</td>
<td>61 (12.5)</td>
<td>76 (16.2)</td>
<td>0.208</td>
</tr>
<tr>
<td>North</td>
<td>270</td>
<td>131 (47.2)</td>
<td>49 (19.0)</td>
<td>48 (16.0)</td>
<td>42 (17.8)</td>
<td></td>
</tr>
<tr>
<td>Center</td>
<td>127</td>
<td>55 (42.2)</td>
<td>33 (25.8)</td>
<td>23 (17.6)</td>
<td>16 (14.4)</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>173</td>
<td>113 (61.2)</td>
<td>29 (21.4)</td>
<td>15 (7.8)</td>
<td>16 (9.5)</td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>123</td>
<td>66 (52.9)</td>
<td>25 (19.2)</td>
<td>14 (11.9)</td>
<td>18 (13.5)</td>
<td></td>
</tr>
<tr>
<td>Socioeconomic level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>40</td>
<td>20 (49.8)</td>
<td>11 (29.3)</td>
<td>5 (10.2)</td>
<td>4 (10.7)</td>
<td>0.167</td>
</tr>
<tr>
<td>B</td>
<td>233</td>
<td>122 (47.1)</td>
<td>59 (31.6)</td>
<td>30 (12.1)</td>
<td>22 (9.2)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>429</td>
<td>204 (47.8)</td>
<td>96 (22.1)</td>
<td>68 (15.5)</td>
<td>61 (14.6)</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>247</td>
<td>134 (52.7)</td>
<td>38 (17.4)</td>
<td>32 (14.0)</td>
<td>43 (15.9)</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>239</td>
<td>127 (52.9)</td>
<td>48 (19.8)</td>
<td>26 (10.3)</td>
<td>38 (17.1)</td>
<td></td>
</tr>
<tr>
<td>Exposure to screens (hours/day)&lt;sup&gt;iii&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 4</td>
<td>167</td>
<td>70 (40.2)</td>
<td>42 (31.2)</td>
<td>25 (12.6)</td>
<td>30 (16.0)</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as number (%).
Number, unweighted count; %, weighted proportion.
<sup>a</sup>p-value estimated under Pearson chi-square test with the second-order Rao-Scott correction.
<sup>b</sup>Estimated for a subpopulation sized=1,159.

Among individuals aged 18 to <30 years, 25.9% reported viewing screens for ≥8 h/day, while only 2.9% of those aged ≥60 years engaged in the same activity. By residence area, 40.1% of participants residing in rural areas reported not viewing screens, whereas this proportion was 21.2% among those living in urban areas. Additionally, individuals with higher socioeconomic status exhibited higher screen usage (Supplementary Table S1).
Ordinal logistic regression

In the first model, the number of hours spent viewing DDCI screens was included as an independent variable, while the covariates comprised sex, age (in years), socioeconomic status, and region. The covariates met the proportional odds assumption in the bivariate analysis, except for age, which had a p-value of 0.006 in contrast to parallel lines. Nevertheless, we applied ordinal logistic regression since the global model met the proportional odds assumption.

Both the complete and reduced models revealed that viewing DDCI screens, sex, and age were independently associated with CNP. In the reduced model, those who viewed screens for ≥8 hours had 61% higher odds of increasing the frequency of CNP from one level to another compared to those who did not view screens or rarely did. Furthermore, females exhibited 2.31 times the odds of increasing the frequency of CNP compared with males, and each additional year of life increased the odds of increasing the frequency of CNP by 2% (Table 5). The post-hoc statistical power reached by the sample was 99.9%, considering the reduced model (three predictors), MacFadden $R^2=0.0299$, a significance level of 5%, and 1,159 observations.

**DISCUSSION**

In Peru, during the transition back to normalcy after the COVID-19 restrictions, the prevalence of CNP occurring daily or almost daily, or at least once a week doubled in comparison to the period preceding the pandemic restrictions (14.8 vs. 6.1 and 27.8% vs. 12.4%, respectively). To our knowledge, this study represents the first attempt to estimate the prevalence of CNP before and after the implementation of pandemic-related social restrictions at a population level. Additionally, we found that DDCI screen viewing for ≥8 h/day increased the frequency of CNP independent of age and sex.

Our findings may diverge from other studies due to methodological differences and population heterogeneity. The high prevalence of CNP observed in our study may be attributed to our approach to pain assessment, which considered the presence of pain without specifying its intensity. Similar to other studies, our pain-related questions gathered information based on pain frequency [24,25]. Through this approach, we classified CNP into persistent pain (daily or almost daily) and recurrent pain (at least once a week) [4,26]. Additionally, it is possible

**Table 5.** Ordinal logistic regression to evaluate the association between viewing at internet-connected electronic devices’ screen and chronic neck pain in the Peruvian population

<table>
<thead>
<tr>
<th>Variate</th>
<th>Model 1 (complete) $^a$</th>
<th>Model 2 (reduced) $^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\beta$</td>
<td>ORa (95% CI)</td>
</tr>
<tr>
<td>Intercept 1</td>
<td>2.31</td>
<td>2.25</td>
</tr>
<tr>
<td>Intercept 2</td>
<td>3.28</td>
<td>3.22</td>
</tr>
<tr>
<td>Intercept 3</td>
<td>4.12</td>
<td>4.05</td>
</tr>
<tr>
<td>No. of hours viewing at screens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
<td>&lt;4</td>
<td>-0.16</td>
<td>0.86 (0.59–1.24)</td>
</tr>
<tr>
<td>4 to &lt;8</td>
<td>0.19</td>
<td>1.21 (0.79–1.85)</td>
</tr>
<tr>
<td>≥8</td>
<td>0.54</td>
<td>1.71 (1.07–2.75)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
<td>Female</td>
<td>0.83</td>
<td>2.28 (1.76–2.95)</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>0.02</td>
<td>1.02 (1.01–1.03)</td>
</tr>
<tr>
<td>Socioeconomic level</td>
<td>0.07</td>
<td>1.08 (0.95–1.22)</td>
</tr>
<tr>
<td>Region</td>
<td>-0.08</td>
<td>0.93 (0.84–1.02)</td>
</tr>
</tbody>
</table>

Intercept 1: Pain on a daily basis versus I have not had pain, pain once a month on average and pain once a week.
Intercept 2: Pain on a daily basis and once a week on average versus I have not had pain and pain once a month on average.
Intercept 3: Pain on a daily basis, pain a week on average and pain once a month versus I have not had pain.

ORa, adjusted odds ratio; 95% CI, 95% confidence interval; Ref, reference.

$^a$Model 1: Test to evaluate the proportional odds assumption: Wald test=1.433, gl1=14.0, gl2=1,158.0, p=0.130. Test of goodness of fit model: Pseudo-R square by McFadden=0.031, Nagelkerke=0.081.

$^b$Model 2: Test to evaluate the proportional odds assumption: Wald test=1.631, gl1=10.0, gl2=1,162.0, p=0.093. Test of goodness of fit model: Pseudo-R square by McFadden=0.0299, Nagelkerke=0.078.

$^c$Test of parallel lines for each independent variate: Wald test p-value.

$^d$The test of parallel lines was applied considering the age in three categories (18 to less than 30, 30 to less than 60, and 60+): Wald test=1.962, gl1=4.0, gl2=1,198.0, p=0.098.
that individuals with mild pain typically do not seek medical attention, making them more likely to be identified in population-based studies. Most epidemiological studies measuring the frequency of CNP during the COVID-19 pandemic were conducted in specific groups, such as university students [11,27,28], office workers [29,30], and outpatients [31], rather than in representative samples from the general population.

Another factor that may affect the comparability of our study results is the definition of the anatomical neck region. In this study, we structured the question to encompass the area below the upper nuchal line and the external occipital protuberance, extending over the scapular spine, the upper edge of the collarbone, and the interclavicular notch, with or without radiation to the head, trunk, and limbs [26]. Some studies have used a duration criterion, defining CNP as pain lasting more than 3 months [26,32]. However, in our study, we adopted a different approach by examining the occurrence of neck pain over the previous 6 months. This observation period criterion ensures that the duration of pain experienced by individuals exceeds 3 months, i.e., more than the time required to heal the tissues or resolve any underlying disease, thereby meeting the criteria for defining a chronic condition.

Studies on CNP prevalence before and after COVID-19 restrictions are limited worldwide, and their results are inconsistent. In Portugal, the prevalence of neck pain among computer workers increased from 45% to 62.5% between June 2019 and January 2021 (the early second year of the pandemic) [30]. However, other studies did not observe this increase. In Switzerland, no changes in CNP intensity or disability rates were found among office workers in the last 4 weeks between data collected in January (10 weeks before restrictions) and April 2020 (5 weeks in lockdown) [29]. In Turkey, the proportion of neck pain in workers who stayed at home decreased from 33.6% to 20.3% during the 3-month lockdown period [33]. One possible explanation for the disparate findings in the latter two studies could be the brief period between measurements, and it is plausible the conditions caused by social restrictions did not lead to significant changes in neck pain within such a short timeframe.

We found that DDCI screen-viewing for ≥8 hours is associated with CNP. The first involves poor head and neck posture. Evidence suggests that neck pain is related to forward head posture, which is common during viewing DDCI screens [36]. However, although a positive correlation exists between forward head posture and increased thoracic kyphosis, thoracic posture and mobility were not uniformly associated with neck pain intensity and disability [37]. This controversy may be explained, at least in part, by a second proposed mechanism related to sedentarism and prolonged static posture. CNP could develop even with a good posture and an ergonomic position of the head and neck because maintaining a fixed position for extended periods could result in degenerative changes of these structures, leading to chronic inflammation and impairments of cervical proprioception [38]. The cervical region exhibits the highest degree of spine mobility, but its vertebral discs and ligaments have minimal vascularization. Nutrients and waste substances are mainly transported through diffusion and convection [39], and therefore dynamic loads are essential to maintaining fluid balance and the integrity of these spine components [40]. When using DDCI for prolonged periods, taking regular breaks to perform active head and neck exercises is essential to maintain neck health. Moreover, if CNP is present, a proper rehabilitation treatment is recommended.

Strengths and limitations
Our study has several strengths. First, the sampling design generated prevalence estimates for the nationwide adult population in Peru according to the country areas (urban/rural) and macro-regions. Second, to our knowledge, this is the first study to compare CNP prevalence before and after the COVID-19 pandemic restrictions on a nationwide scale. This is particularly noteworthy as previous studies have primarily estimated this change in specific occupational groups or patients attending healthcare facilities. Third, the survey was conducted in a structured manner using questions previously applied in a population study in 2016 [20], thus allowing for a comparison of CNP prevalence changes over time. Fourth, this study placed emphasis on measuring pain specifically in the cervical region.
Consequently, the questions were tailored to target this specific body area, unlike other studies that employed more generalized assessments or evaluated pain across multiple body areas. This approach served to mitigate recall bias.

This study also has some limitations. Firstly, the identification of CNP was based on self-reports rather than case history or physical examination conducted by healthcare professionals. Secondly, estimates of pre-pandemic CNP rates may be subject to recall bias, as participants (interviewed in November 2022) were asked to remember the presence and frequency of neck pain in March 2020 and at least 6 months earlier. However, it is known that the presence of unusual historical or major events (in this case, the beginning of the pandemic lockdown) tends to improve recall. Thirdly, certain population characteristics, such as education, occupation, or history of COVID-19, were not captured to better characterize the distribution of CNP. This limitation also extended to the study of the relationship between CNP and screen-viewing as they were not included as potential confounders. Fourthly, exposure was also measured via self-reports, and establishing a causal association with CNP was challenging due to the inability to define the temporal sequence between exposure and outcome. Lastly, our study did not explore the intensity or specific causes of CNP.

In conclusion, after lifting COVID-19 social restrictions in Peru, CNP occurring daily or almost daily, or at least once a week, affected approximately four out of ten adults, representing over a two-fold increment compared to the pre-pandemic values. The most affected subgroups were females and adults aged >60 years. Additionally, those who spent ≥8 h/day viewing DDCI screens were at increased risk of suffering CNP compared to those who did not, and this association was found to be independent of age and sex. These findings underscore the broader public health challenges stemming from the COVID-19 pandemic. Moreover, our research revealed that viewing DDCI screens for extended periods is a specific and modifiable risk factor, which is more widely spread across the general population and a potential target for developing preventive strategies to reduce the prevalence of CNP and accompanying disabilities.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

FUNDING INFORMATION

The study had partial funding from the Universidad de Piura, Lima, Peru (Grant No. PI-2305).

AUTHOR CONTRIBUTION


SUPPLEMENTARY MATERIALS

Supplementary materials can be found via https://doi.org/10.5535/arm.230030.

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Establishing Reference Values for a New Computerized Cognitive Function Test Program for Children

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Objective: To establish reference values for the computerized cognitive test and evaluate cognitive function improvements across different age groups, we introduce the computerized Cognitive Function Test program (eCFT), specifically designed for children. We aimed to establish eCFT reference values and assess cognitive function improvements across different age groups.

Methods: We included children aged 3–6 years with confirmed normal cognition based on the Korean Developmental Screening Test for Infants and Children and Kaufman Assessment Battery for Children-II. The eCFT consists of 8 subtests for visual perception, attention, memory, and executive function.

Results: A total of 66 participants (36 males and 30 females) with an average age of 4.4 years participated. The age 6 group consistently outperformed both age group 3 and 4 in terms of correct responses. With regard to the completed stage, the “selective auditory stimulus” test findings were 2.0 and 3.9 for the age 3 and age 6 groups, respectively (p<0.05). The “trail-making” test findings were 1.7, 2.1, 2.6, and 2.8, respectively (between ages 3 and 6, p<0.01; between ages 4 and 6, p<0.05); moreover, the age 5 group surpassed the age 3 group (2.6 and 1.7, respectively, p<0.05).

Conclusion: The eCFT is an easily accessible tool to evaluate cognitive function in young children. We introduce reference values with a cutoff range for preschool-aged children, enabling early intervention for those with cognitive impairment. Given its accessibility and relatively short evaluation time, the eCFT has potential for clinical use.

Keywords: Cognition, Cognitive dysfunction, Child, Neuropsychological tests, Computerized Cognitive Function Test program

INTRODUCTION

Cognitive function plays a crucial role in children’s independence in daily activities and social engagement [1]. Cognitive rehabilitation is necessary to treat children with cognitive impairment or developmental delays because it can prevent cognitive decline and reduce social costs [2,3]. The effectiveness of cognitive rehabilitation has been demonstrated in patients with cognitive impairments [4,5] and it has even been shown to improve cognitive function in children without overall learning difficulties [5]. Although cognitive rehabilitation can be achieved through pharmacological or non-pharmacolog-
ical treatments, more careful consideration is needed when administering medications for children owing to the negative perception of caregivers and patients towards medications, and concerns about potential side effects. Additionally, there is more substantial evidence supporting the use of pharmacological intervention in adults, while the data regarding their efficacy and safety in children is insufficient [6-10]. However, traditional programs such as one-on-one or group therapy may be unavailable or impractical because of resource limitations and health conditions [11].

Computerized cognitive training (CCT) can compensate for these shortcomings, and several CCT programs, including RehaCom (HASOMED), ComCog (neofect), and Bettercog (M3 Solutions), have demonstrated effectiveness in enhancing cognitive function in individuals with cognitive impairment. RehaCom has shown its efficacy in improving cognitive function in children with ADHD and chronic stroke patients [12,13]. ComCog has demonstrated cognitive improvement in individuals with mild cognitive impairment (MCI), stroke, traumatic brain injury (TBI) patients [14,15]. In addition, ComCog has exhibited greater cognitive enhancement in a young TBI group than in an old TBI group [16].

The accurate evaluation of cognitive function is essential prior to rehabilitation. Computerized cognitive function tests serve as practical and accessible tools for this purpose, as they help reduce the examiner’s workload, minimize the variability introduced by human assessors, enable automated data storage, and capture reaction time data. Several Computerized Cognitive Test Batteries are available for children [17,18]. Cambridge Neuropsychological Test Automated Battery is the most frequently used one and it is only applicable for children aged 4 years and above [18]. The National Institutes of Health Toolbox Cognition Battery and Amsterdam Neuropsychological Test are the only tests that can be applicable from the age of 3, while others can be employed for children aged 4–5 and above [18].

The computerized Cognitive Function Test program (eCFT) is a newly developed online cognitive function test that is part of the Bettercog (computerized cognitive rehabilitation program) developed in Korea. The eCFT is specifically designed to assess cognition in Korean children aged 3 and above, using words and images which are familiar to Korean children. It utilizes a touchscreen-based interface for user interactions. We, therefore, aimed to establish reference values for the eCFT and to investigate whether there is a trend of increasing cognitive function with age.

New Computerized Cognitive Function Test Program for Children

METHODS

Participants

We included children aged 3–6 years who were identified as having normal cognition through the Korean Developmental Screening Test for Infants and Children (K-DST) and Kaufman Assessment Battery for Children-II (K-ABC-II) test. Based on previous studies’ methodology, we aimed to recruit 15 subjects per age group [19, 20].

The participants were recruited via poster advertisements at the National Traffic Injury Rehabilitation Hospital and the study was conducted from November 2021 to September 2022. The exclusion criteria were hearing difficulties, visual impairments, hemi-neglect, and other musculoskeletal or neurological disorders that could impede following the instructions. The participants visited the research lab once to complete the K-DST, K-ABC-II, and eCFT. The assessments were conducted by a single occupational therapist, with a total duration of approximately 2 hours, including approximately 40 minutes for the eCFT.

The K-DST is a standardized questionnaire completed by caregivers to identify developmental delays in children. It evaluates various domains, such as motor skills, language, social and personal skills, and problem-solving ability [21,22]. It consists of six domains, each with a scoring range from 0 to 24 points. If a domain score is more than 1 standard deviation (SD) above the mean within the age group, it indicates a potentially higher-than-average developmental level. Scores within ±1 SD represent normal development. Scores below -1 SD and greater than -2 SD indicate a need for continuous observation. Scores below -2 SD suggest developmental delay, requiring further evaluation. The revised 2017 version was used in this study [23]. The K-ABC-II is a standardized test designed to measure cognitive ability and achievement in children and adolescents, to assess cognitive domains, including memory, planning, attention, and problem-solving abilities [24]. It comprises five domains and 18 subtests, with each subtest having a maximum scale score ranging from 1 to 19 points. Depending on the child’s age, subtests are selectively administered rather than conducting all 18 subtests on each child. Test results are interpreted using standard scores, with a mean of 100 and a SD of 15, and a maximum score of 160. Standard scores within ±1 SD are considered “average,” scores below -1 SD and greater than -2 SD are “low,” scores below -2 SD are “very low,” scores higher than +1 SD and below +2 SD are “high,” and scores higher than +2 SD are “very
high.” The Korean version of the test was used to assess the cognitive function in this study [25].

**Computerized program description**

The eCFT consists of 8 subtests designed to evaluate various cognitive domains, including visual perception, attention, memory, and executive function. These subtests are: “finding half,” “visual and auditory stimulus,” “flip sequence,” “delayed recall,” and “trail-making.” Table 1 presents the instructions for each subtest. The “finding half” test was used to assess visual perception. The “visual and auditory stimulus” test evaluates attention and reaction time, while the “selective visual” and “selective auditory” stimulus tests measure complex attention and reaction times. The “flip sequence” test is designed to assess immediate memory and the “delayed recall” test focuses on delayed memory. The “trail-making” test is a tool to evaluate working memory.

Each subtest has unique characteristics and requirements. The “finding half” test requires participants to respond to each of the 20 questions within a 10-second timeframe. The “visual stimulus,” “selective visual stimulus,” “auditory stimulus,” and “selective auditory stimulus” tests are structured across 5 stages each. The “visual” and “auditory” stimulus tests present 5 stimuli at each stage, for a total of 25 questions, while the “selective visual” and “selective auditory stimulus” tests feature 3 true and false stimuli in each stage, resulting in a total of 30 questions. False stimuli were presented randomly, and the stimulation and interval times were modified to adjust the difficulty level of each stage. For the “visual” and “selective visual stimulus tests,” the stimulation times per stage were set to 4, 2.5, 2, 1.5, and 1 second. Unlike that in visual stimuli, it was challenging to maintain a constant stimulation time for auditory stimuli and it was adjusted only by the interval time. The interval time for all four tests was consistently set to 3, 2.5, 2, 1.5, and 1 second [26].

The “flip sequence” test comprises five stages, with a total of 20 questions. The interval time ranged from 3 to 5 seconds. Lower and higher stages were evaluated with a 3- and 5-second interval, respectively. This means that participants were required to remember the “flip sequence” for 3 to 5 seconds before recalling it, and they were required to answer each question within 10 seconds [27]. The “delayed recall” test consists of a single stage comprising 10 questions. Participants are shown two pictures for 5 seconds, followed by playing “Whack-A-Mole” for 10 seconds. Following this, they are required to recognize the previously displayed pictures from a set of five within the given 10 seconds. The trail-making test comprised 3 stages. In the first stage, the participants were instructed to click on the order of the rainbow colors. In the second stage, they were required to click from 1 to 7, and, in the final stage, they alternated between rainbow colors and numbers. The participants were required to respond to each stage within 2 minutes. The test time was shortened if the participants responded earlier than the given time or failed a stage.

**Outcome measures**

The data collected from the eCFT included the number of correct answers, incorrect answers, incomplete responses, completed stages, and reaction times.

**Statistical analysis**

Statistical analyses were performed using the IBM SPSS statistics 23 (IBM Corp.). Descriptive statistics, such as mean, SD, 15th percentile, and 85th percentile of the number of correct answers and reaction time, were presented. An analysis of variance was used to compare mean differences across age groups, and a post hoc Games–Howell test was conducted to determine specific mean differences. Statistical significance was set at p<0.05.

**Ethics approval**

This study adhered to the Declaration of Helsinki (2013 revision) and ICH-GCP guidelines. The study received approval from the Institutional Review Board of Seoul National University Hospital (IRB No. 2107-171-1236) and from the Institutional Review Board of National Traffic Injury Rehabilitation Hospital (IRB No. 2021-10-022). Informed consent was obtained from legally authorized representatives.

**RESULTS**

We included 66 participants (36 males) aged 3–6 years old (mean, 4.4 years old). None of the participants had a significant medical history and information regarding their socioeconomic status was not collected for this study.

The results of the K-DST and K-ABC-II are presented in Table 2. For the K-DST, the average score was 127.2±10.8. The total scores per age group were 128.9, 126.4, 124.9, and 137.5, respectively. In the K-ABC-II, the average score was 158.4±50.2. The total scores for each age group were 104.3, 143.9, 188.0, and 204.4. All participants scored within the normal range on the K-DST and K-ABC II tests.

Table 3 presents the results of the 8 eCFT subtests, including
Table 1. Computerized Cognitive Function Test program (eCFT) task description: 8 subtests

<table>
<thead>
<tr>
<th>eCFT task</th>
<th>Display</th>
<th>Cognitive domain</th>
<th>Test description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finding half</td>
<td></td>
<td>Visual perception</td>
<td>Half of a picture is presented. Find the corresponding half</td>
</tr>
<tr>
<td>Visual stimulus</td>
<td></td>
<td>Attention, reaction time</td>
<td>Touch the screen when a picture is presented</td>
</tr>
<tr>
<td>Selective visual stimulus</td>
<td></td>
<td>Complex attention, reaction time</td>
<td>Touch the screen when a specific picture appears and refrain from touching the screen when other pictures appear</td>
</tr>
<tr>
<td>Auditory stimulus</td>
<td></td>
<td>Attention, reaction time</td>
<td>Touch the screen when a sound is heard</td>
</tr>
<tr>
<td>Selective auditory stimulus</td>
<td></td>
<td>Complex attention, reaction time</td>
<td>Touch the screen when certain sounds are heard, and refrain from touching the screen when other sounds are heard</td>
</tr>
<tr>
<td>Flip sequence</td>
<td></td>
<td>Immediate memory</td>
<td>Coins are flipped in a specific order. After a few seconds, participants are required to repeat the order of the flips</td>
</tr>
<tr>
<td>Delayed recall</td>
<td></td>
<td>Delayed memory</td>
<td>Two pictures are presented. Play Whack-A-Mole for 10 seconds. Of the 5 pictures, select the 2 previously presented</td>
</tr>
<tr>
<td>Trail-making</td>
<td></td>
<td>Working memory</td>
<td>Step 1. Click in order of rainbow colors</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Step 2. Click from 1 to 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Step 3. Click the rainbow color and number alternately</td>
</tr>
</tbody>
</table>
Table 2. Demographic and clinical characteristics

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>N (female, %)</th>
<th>K-DST</th>
<th>K-ABC-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>15 (8, 53.3)</td>
<td>128.9±7.8 (117, 142)</td>
<td>104.3±16.9 (62, 127)</td>
</tr>
<tr>
<td>4</td>
<td>21 (7, 33.3)</td>
<td>126.4±12.1 (103, 140)</td>
<td>143.9±38.8 (104, 298)</td>
</tr>
<tr>
<td>5</td>
<td>16 (8, 50.0)</td>
<td>124.9±11.5 (100, 137)</td>
<td>188.0±34.6 (147, 269)</td>
</tr>
<tr>
<td>6</td>
<td>14 (7, 50.0)</td>
<td>137.5±9.2 (131, 144)</td>
<td>204.4±39.0 (143, 275)</td>
</tr>
<tr>
<td>Total</td>
<td>66 (30, 45.5)</td>
<td>127.2±10.8</td>
<td>158.4±50.2</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation (minimum, maximum).

K-DST, Korean Developmental Screening Test for Infants and Children; K-ABC-II, Kaufman Assessment Battery for Children-II.

Table 3. Test results according to age group

<table>
<thead>
<tr>
<th>Test</th>
<th>Age (yr)</th>
<th>N</th>
<th>Number of correct answers</th>
<th>Mean±SD</th>
<th>Reaction time</th>
<th>Reaction time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>15th %</td>
<td>85th %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finding half</td>
<td>3</td>
<td>12</td>
<td>13.5±5.4 8.8</td>
<td>19.0</td>
<td>4.01±1.78</td>
<td>2.32</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>21</td>
<td>18.3±2.3 15.3</td>
<td>20.0</td>
<td>3.61±1.54</td>
<td>2.37</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>15</td>
<td>18.3±1.4 17.0</td>
<td>19.6</td>
<td>3.28±1.50</td>
<td>1.97</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>14</td>
<td>17.1±4.6 15.3</td>
<td>20.0</td>
<td>2.53±1.04</td>
<td>1.66</td>
</tr>
<tr>
<td>Visual stimulus</td>
<td>3</td>
<td>13</td>
<td>17.9±4.6 11.1</td>
<td>22.0</td>
<td>1.30±0.52</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>21</td>
<td>21.4±4.0 17.3</td>
<td>24.0</td>
<td>0.96±0.48</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>15</td>
<td>20.9±2.0 13.6</td>
<td>25.0</td>
<td>0.81±0.39</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>14</td>
<td>24.6±1.1 24.0</td>
<td>25.0</td>
<td>0.58±0.24</td>
<td>0.42</td>
</tr>
<tr>
<td>Selective visual stimulus</td>
<td>3</td>
<td>12</td>
<td>22.9±13.1 5.0</td>
<td>31.2</td>
<td>1.00±0.51</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>21</td>
<td>24.6±5.9 17.3</td>
<td>29.0</td>
<td>0.70±0.51</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>15</td>
<td>26.3±4.3 20.4</td>
<td>29.6</td>
<td>0.61±0.44</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>14</td>
<td>32.1±9.8 26.0</td>
<td>48.8</td>
<td>0.44±0.37</td>
<td>0.13</td>
</tr>
<tr>
<td>Auditory stimulus</td>
<td>3</td>
<td>11</td>
<td>14.5±5.8 6.6</td>
<td>22.0</td>
<td>1.14±0.65</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>21</td>
<td>16.9±6.4 7.6</td>
<td>23.0</td>
<td>1.14±0.53</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>15</td>
<td>19.9±5.2 12.6</td>
<td>24.2</td>
<td>1.08±0.52</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>14</td>
<td>23.8±1.9 20.8</td>
<td>25.0</td>
<td>0.91±0.38</td>
<td>0.61</td>
</tr>
<tr>
<td>Selective auditory stimulus</td>
<td>3</td>
<td>10</td>
<td>4.4±2.3 2.0</td>
<td>7.4</td>
<td>1.85±0.69</td>
<td>1.27</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>19</td>
<td>6.5±3.5 7.0</td>
<td>11.0</td>
<td>1.49±0.56</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>15</td>
<td>8.9±6.4 3.3</td>
<td>12.5</td>
<td>1.40±0.37</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>14</td>
<td>13.8±8.6 5.3</td>
<td>27.8</td>
<td>1.27±0.50</td>
<td>0.86</td>
</tr>
<tr>
<td>Flip sequence</td>
<td>3</td>
<td>14</td>
<td>9.5±7.8 1.0</td>
<td>20.5</td>
<td>4.48±2.41</td>
<td>1.79</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>20</td>
<td>11.5±8.0 1.2</td>
<td>21.9</td>
<td>3.34±2.10</td>
<td>1.38</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>15</td>
<td>15.0±10.9 1.3</td>
<td>28.8</td>
<td>3.49±2.06</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>14</td>
<td>22.8±7.6 12.8</td>
<td>28.8</td>
<td>3.71±2.18</td>
<td>1.63</td>
</tr>
<tr>
<td>Delayed recall</td>
<td>3</td>
<td>11</td>
<td>7.1±3.3 2.4</td>
<td>10.0</td>
<td>5.13±2.22</td>
<td>3.30</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>20</td>
<td>6.0±3.2 1.0</td>
<td>9.0</td>
<td>4.53±1.95</td>
<td>2.64</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>14</td>
<td>7.6±2.2 4.8</td>
<td>9.8</td>
<td>4.11±1.82</td>
<td>2.47</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>12</td>
<td>9.3±1.0 8.0</td>
<td>10.0</td>
<td>3.60±1.42</td>
<td>2.42</td>
</tr>
<tr>
<td>Trail-making</td>
<td>3</td>
<td>14</td>
<td>6.0±6.6 0.0</td>
<td>14.0</td>
<td>4.63±3.73</td>
<td>1.30</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>19</td>
<td>10.2±8.7 0.0</td>
<td>20.0</td>
<td>3.66±3.34</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>15</td>
<td>15.8±8.2 3.3</td>
<td>26.8</td>
<td>2.94±2.92</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>13</td>
<td>22.5±8.0 15.3</td>
<td>28.0</td>
<td>2.16±1.80</td>
<td>0.78</td>
</tr>
</tbody>
</table>

SD, standard deviation.

*a*Visual stimulus test between age 3 and age 6, p=0.001.

*b*Visual stimulus test between age 4 and age 6, p=0.011.

*c*Auditory stimulus test between age 3 and age 6, p=0.001.

*d*Auditory stimulus test between age 4 and age 6, p=0.001.

*e*Selective auditory stimulus test between age 3 and age 6, p=0.010.

*f*Selective auditory stimulus test between age 3 and age 6, p=0.001.

*g*Delay recall test between age 3 and age 6, p=0.001.

*h*Delay recall test between age 4 and age 6, p=0.001.

*i*Trail making test between age 3 and age 6, p=0.001.

*j*Trail making test between age 4 and age 6, p=0.002.

*k*Trail making test between age 3 and age 5, p=0.017.

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the number of participants, SD, 15th percentile, and 85th percentile for both the number of correct answers and the reaction time. A cutoff value at the 15th percentile, equivalent to 1 SD, was employed to identify abnormal performance.

The results demonstrate a progressive improvement in the number of correct answers with increasing age (Fig. 1). Improvements in the "selective visual stimulus," "auditory stimulus," "selective auditory stimulus," "flip sequence," and "trail-making" tests were observed in children aged 3–6 years. The age 6 group exhibited significantly superior performance compared to the age 3 and 4 groups in the "visual stimulus" test (age 3 group: 17.9±4.6, age 4 group: 21.4±4.0, and age 6 group: 24.6±1.1; between ages 3 and 6, p=0.001 and between ages 4 and 6, p=0.011). The age 6 group outperformed the age 3 group and the age 5 group achieved a higher score than the age 4 group in the "auditory stimulus" test (age 3 group: 4.4±2.3 and age 6 group: 13.3±8.6, p=0.010). In the "flip sequence" test, the age 6 group performed significantly better than the age 3 and 4 groups (age 3 group: 9.5±7.8, age 4 group: 11.5±8.0 and age 6 group: 22.8±7.6; between ages 3 and 6, p=0.001 and between ages 4 and 6, p=0.001), and in the "delayed recall" test, the age 6 group surpassed the performance of the age 4 group (age 4 group: 6.0±3.2 and age 6 group: 9.3±1.0, p=0.001). The age 6 group achieved higher scores than the age 3 and 4 groups in the "trail-making" test (age 3 group: 6.0±6.6, age 4 group: 10.2±8.7, age 5 group: 15.1±8.2, and age 6 group: 22.5±8.0; between ages 3 and 6, p<0.001 and between ages 4 and 6, p=0.002), while the age 5 group outperformed the age 3 group (p=0.017).

Although the reaction time tended to decrease as the children’s age increased, the difference was not statistically signifi-

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**Fig. 1.** Comparison of cognitive function scores among age groups per subset. (A) Attention. (B) Memory. (C) Working memory. *p<0.05, **p<0.01, and ***p<0.001.
cant. Regarding the completed stages, the age 6 group completed more stages than the age 3 group in the selective auditory stimulus test. The average completed task stage was 2.0 for the age 3 group and 3.9 for the age 6 group (p<0.05; Fig. 2). The task completion rates for passing up to stage 5 were as follows: 10% for the age 3 group, 11% for the age 4 group, 14% for the age 5 group, and 57% for the age 6 group. In the “trail-making” test, the age 6 group completed more stages than the age 3 and 4 groups did, while the age 5 group completed more stages than the age 3 group did. The average completed task stage was 1.7 for the age 3 group, 2.1 for the age 4 group, 2.6 for age 5 group, and 2.8 for the age 6 group (between ages 3 and 6, p<0.01; between ages 4 and 6, p<0.05; and between ages 3 and 5, p<0.05). The task completion rates for passing up to stage 3 were as follows: 29% for the age 3 group, 47% for the age 4 group, 79% for the age 5 group, and 92% for the age 6 group.

DISCUSSION

We evaluated age-specific differences in eCFT results among children without cognitive impairment and proposed cutoff values based on the 15th percentile of the number of correct answers and reaction time for each subtest. The eCFT results indicated a pattern of increasing correct responses and decreasing reaction times with age. Notably, age 6 group consistently outperformed both age groups 3 and 4 in terms of correct responses. In the “selective auditory stimulus” test, the age 6 group demonstrated higher task completion rates compared to the age 3 group. In the “trail-making” test, the age 6 group completed more task stages than both the age 3 and age 4 groups. To the best of our knowledge, this is the first study to establish reference values for computerized cognitive assessments tailored specifically to preschool-aged children with typical cognitive development in Korea.

Our findings revealed that the mean performance scores in
each cognitive domain showed slight variations depending on the child's age, with older children tending to achieve higher scores. Notably, the age 6 group consistently outperformed the age 3 and 4 groups across various subtests. Furthermore, older groups tended to exhibit shorter reaction times in the attention domain, although this trend was not statistically significant. However, this pattern of shorter reaction times with increasing age was not observed in the findings of the "flip sequence" test. In other words, in challenging tasks such as memory function tests, younger children can exhibit shorter reaction times with lower accuracy than those exhibited by older children.

Furthermore, reaction time is directly related to attention. In a previous study, the average reaction time in the visual Continuous Performance Test (CPT) for typical Korean adults was reported as 0.42 seconds, while in the auditory CPT, it was 0.59 seconds [26]. In our study, the 6-year-old participants exhibited mean reaction times of 0.58 seconds in the "visual stimulus" test and 0.91 seconds in the "auditory stimulus" test, which differs from adults. The lower reaction time in the age 6 group compared to that of adults could be derived from either motor control or attention-related issues. Examining the results of the auditory stimulus test can further elaborate this. The average reaction time for visual and auditory controlled CPT (CCPT) in adults was reported as 0.41 and 0.57 seconds, respectively. Additionally, the average reaction times for the "selective visual stimulus" and "selective auditory stimulus" tests were 0.44 and 1.27 seconds, respectively, in the age 6 group. This suggests that inhibitory responses to auditory stimuli are somewhat more challenging than those to visual stimuli, and it implies that the difference observed in visual stimuli may be attention-related and attributed to processing speed rather than motor control [26]. In another study [19], a computerized attention assessment for children aged 5 to 15 years was developed, which was used to evaluate auditory CCPT and visual CCPT, dividing the total assessment time into three phases (early, middle, and late). The test provided target ratios of 22% in the early phase, 50% in the middle phase, and 78% in the late phase, and it maintained a fixed stimulus interval of 2 seconds and a stimulus presentation time of 0.1 seconds. The results revealed that the average reaction time for visual CCPT in 5- and 6-year-olds was 0.67 and 0.61 seconds, respectively, whereas our eCFT “selective visual stimulus” reported 0.61 and 0.44 seconds, respectively. For auditory CCPT, the average reaction time in 5- and 6-year-olds was 1.07 seconds, and our eCFT’s "selective auditory stimulus" test reported 1.40 and 1.27 seconds, respectively [19].

Regarding the completed stages, statistically significant differences were observed only in the "selective auditory stimulus" test and "trail-making" test. There were no differences in other attention-related subtests or the "flip sequence" test. This could be interpreted as indicating that executive function in 6-year-olds significantly outpaces that in other age groups, and that they exhibit superior sustained attention and better impulsivity control.

In addition, accurate responses to auditory stimuli are often lower than those to visual stimuli. In particular, the "selective auditory stimulus" test is challenging because of inhibition [19]. Our findings have corroborated this trend, revealing significant differences in the "selective auditory stimulus" among the completed stages.

The "trail-making" test assess motor speed, speed of mental processing and mental flexibility. It was used for children with learning disabilities and attention problems as well as those affected by brain injury [28]. In a study involving children aged 9 to 14, the alternative (number-letter) "trail-making" test was conducted, dividing participants into three groups: a group with brain injuries, a group with academic difficulties, and a control group. The test involved connecting 15 numbers and 15 letters alternatively. The completion times differed significantly, with the brain-damaged, academic difficulties, and control groups requiring 111.44, 68.38, and 33.56 seconds, respectively, to finish the test. [29]. As our study targeted children aged 3 to 6 years, the "trail-making" test used in our study utilized numbers 1–7 and colors (red, orange, yellow, green, blue, indigo, and violet). The average completion times of step 3 for the age 3, age 4, age 5, and age 6 groups were 68.54, 53.71, 44.73, and 36.17 seconds, respectively (not presented in Table). However, the number of individuals who completed the step 3 varied. In the age 3, age 4, age 5, and age 6 groups; 4/14, 9/19, 11/14, and 12/13 participants, respectively, completed the test. Even when examining normally developing children, there were instances where individuals did not successfully complete the alternative “trail-making” test. Therefore, considering these challenges, the use of the “alternating selection (step 3)” test might be more suitable for older age groups than that of the other test.

Computerized tests offer several advantages, including reducing the burden of examiners, minimizing variation by examiners, automatically storing data, obtaining information about reaction time, and allowing testing to be done at home [19], and have, therefore, gained popularity. The BMT-i, computerized Adaptable Test Battery to assess children’s academic skills and
Measuring reaction time is a good screening tool for normal aging and MCI, and it is more accurate than measuring correct answers in adults aged >60 years of age [30]. Previous studies established a correlation between processing speed and overall cognitive performance [31]. Notably, individuals diagnosed with ADHD exhibit challenges in sustaining attention and show significant impairments in selective attention as they have higher rates of omission and commission errors. In the case of unpredictable stimulus, children with ADHD tend to make a substantial number of those errors [32,33].

This study has certain limitations. First, it was conducted within a specific region of Korea, which potentially limits the generalizability of our results to other populations. Second, the small sample size may have contributed to the not significant differences between the groups. For instance, in the “selective visual” test, the age 6 group obtained considerably higher scores than the other groups (scores: 22.9, 24.6, 26.3, and 32.1 for ages 3, 4, 5, and 6, respectively), although this difference did not reach statistical significance. It is plausible that a larger sample size would reveal significant differences. Third, we did not collect detailed information about the patients’ characteristics, such as their socioeconomic status, number of siblings, and parental education levels. These factors may have influenced our results. Forth, we used colors (red, orange, yellow, green, blue, indigo, and violet) instead of letters in the “trail-making” test. This was done to avoid the possible unfamiliarity of very young children with letters. However, the test may not have been accurately conducted for children with color blindness, considering that we did not conduct a screening test for color blindness.

Using the eCFT, we established reference values for each subtest within the age range of 3–6 years, providing insights into the cognitive development of preschool children without cognitive impairment. Our findings indicated a progressive improvement in cognitive performance with age, which was particularly evident in specific subtests. The eCFT, known for its accessibility and cost-effectiveness, holds great promise for clinical application in identifying cognitive impairment and facilitating early intervention in preschool-aged individuals.

Future research should explore the potential of the eCFT as a tool to distinguish between children with and without cognitive impairments, such as those with low academic skills or attention deficits. Additionally, further investigations may seek to identify the age at which children’s scores on the eCFT begin to plateau in a specific cognition domain.

CONFLICTS OF INTEREST
The funding for this research was provided by M3 SOLUTIONS, CO., LTD, with Seoul National University Hospital serving as the lead research institution. This work falls under the category of commissioned research and the M3 Company played no role in the research design, data collection, analysis, or interpretation of results. The funding covered research expenses, equipment acquisition, and publication costs, with no influence on the research findings. The research was conducted independently, and the researchers maintained academic independence regarding the interpretation of the research results.

FUNDING INFORMATION
The funding for this research was provided by M3 SOLUTIONS, CO., LTD, with Seoul National University Hospital serving as the lead research institution (grant number: 0620214740). This work falls under the category of commissioned research.

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Feasibility of Computerized Visuomotor Integration System for Visual Field Defects and Spatial Neglect in Poststroke Patients

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Objectives: To develop a computerized visuomotor integration system for assessment and training of visual perception impairments and evaluate its safety and feasibility in patients with a stroke. Visual field defects and spatial neglect lead to substantial poststroke impairment. Most diagnostic assessments are anchored in traditional methods, and clinical effects of rehabilitation treatments are limited.

Methods: The CoTras Vision system included two evaluations and four training modules. The evaluation modules were based on the Albert’s test and Star cancellation test, and training modules were based on visual tracking, central–peripheral integration, and visuomotor perception techniques. Bland–Altman plots for agreement with the traditional paper-and-pencil test were performed, and the modified Intrinsic Motivation Inventory, Patient Satisfaction Questionnaire, and Simulator Sickness Questionnaire were conducted.

Results: Ten patients with acute stroke completed the study. Bland–Altman plots revealed good agreements for Albert’s test (mean difference, -0.3±4.5) and Star cancellation test (mean difference, 0.3±0.7). The mean±standard deviation scores of the modified Intrinsic Motivation Inventory, Patient Satisfaction Survey, and Simulator Sickness Questionnaire were 84.7±30.6, 40.5±7.9, and 34.0±34.5 respectively.

Conclusion: The CoTras Vision system is feasible and safe in patients with stroke. Most patients had a high degree of motivation to use the system and did not experience severe adverse events. Further studies are needed to confirm its usefulness in stroke patients with visual field defects and hemineglect symptoms. Furthermore, a large, well-designed, randomized controlled trial will be needed to confirm the treatment effect of the CoTras Vision system.

Keywords: Stroke, Visual fields, Spatial neglect, Rehabilitation

INTRODUCTION

The prevalence of stroke is increasing globally, and it has become the second most common cause of death [1]. A number of patients who experience a stroke develop visual perception disorders, including visual field defects (VFDs) and spatial neglect [2]. In stroke-related VFD, the optic nerve is not directly injured, but the damage to the visual center—which perceives vi-
sual information—results in a blind spot within the field of view [3,4]. In spatial neglect, the attention and spatial perception on the side contralateral to that of the brain lesion decrease, rendering it unresponsive to external stimuli [5]. Visual perception disorders in patients who have had a stroke greatly impact the safety of daily activities, such as walking or driving, increase the medical burden due to sequelae, and reduce the quality of life of the patient and their caregivers [6,7].

The current assessment tools for VFD and spatial neglect are not advanced or refined beyond the traditional paper-and-pencil test, and most rehabilitation strategies are anchored in the compensatory method [8-10]. Non-invasive brain stimulation and compensatory techniques using virtual reality, mirror therapy, prism eyeglasses, and devices such as the Dynavision (Dynavision International) have been developed to assist patients in recovering from visual perception disorders [11,12]. However, these treatments are still being under investigation and have yielded limited outcomes. Therefore, a more effective and efficient treatment method is needed [13-15].

Recently, a variety of computer-based rehabilitation systems and smart device applications have been developed for patients with VFDs and spatial neglect and are being used in clinical practice [16-18]. The recent coronavirus disease pandemic also led researchers to conduct such studies. In this study, we aimed to develop a computer-based visuomotor integration system for the functional assessment and rehabilitation training in patients with VFDs and spatial neglect following a stroke. Additionally, we assessed its usability, safety, and level of satisfaction in patients with acute stroke.

**METHODS**

This study was conducted after obtaining approval from the Institutional Review Board (IRB) of Keimyung University Dongsan Hospital (IRB No. 2022-11-048). Patients and their caregivers were given a sufficient explanation of the objectives and procedures of the study, after which they had to provide informed consent before being enrolled.

**Patients**

Patients who were admitted to our hospital from March 2023 to May 2023 for a stroke were enrolled in this study. The inclusion criteria were as follows: (1) first stroke; (2) age between 18 and 85 years; and (3) stroke within the past 6 months. The exclusion criteria were as follows: (1) severe upper extremity weakness (Medical Research Council scale score <3); (2) cognitive impairment rendering a patient unable to follow directions; and (3) diagnosis of psychiatric or neurological disease(s) prior to stroke. Since the main purpose of this study was to assess the usability, safety, and applicability of the newly developed device, we included the entire cohort of stroke patients with or without hemineglect or VFDs symptoms.

**CoTras Vision**

CoTras Vision (COTRAS) was developed for functional assessment and rehabilitation training for VFDs and spatial neglect. This system consists of a desktop computer and a large touch screen (Fig. 1) and is easy to transport because it has wheels. The height and angle of the touch screen can be adjusted between 128.5 and 193.5 cm and 0° and 90°, respectively, to

![Fig. 1. Configuration of the CoTras Vision system (COTRAS).](image-url)
accommodate the user’s height and arm length. Therefore, patients in wheelchairs can also use it.

CoTras Vision includes two functional assessments and four rehabilitation training modules. All assessments and training programs are conducted while the user sits 30–50 cm away from the screen and focuses on the center of the screen. Each assessment and training module is performed for a specified length of time, which can be modified in 30-second increments, from 30 seconds to 6 minutes, according to the condition of the patient. In visual tracking, the speed of the object on the screen can be adjusted in 10 steps.

Functional assessment using the system consists of the Albert’s test and the Star cancellation test, which are computerized versions of the traditional paper-and-pencil tests. The touch screen interface was constructed to closely mimic the traditional method of using a pen. In this study, a 5-minute time limit was set, at which point the test was terminated regardless of its completion (Fig. 2).

Rehabilitation training using the system consists of the visual tracking, visual perception training, central peripheral integration, and digit selection modules. In visual tracking, the patient’s gaze has to follow an object on the screen moving in different patterns, such as a star, curve, or line pattern, without head movement. In visual perception training, patients fix their gaze on a circle in the center of the screen and respond by touching the circle that randomly appears on the monitor. In central peripheral integration, patients are trained to touch a randomly appearing circle that is of the same color as the one in the center of the screen as quickly as possible while keeping their face and gaze fixed on the center of the screen. In digit selection, patients detect and touch the number that is the same as the one that appears in the top middle of the screen from six rows of 14 numbers presented sequentially from left to the right (Fig. 2).

**Patient-reported outcome measures**

The patients completed the modified Intrinsic Motivation Inventory (mIMI), Patient Satisfaction Questionnaire, and Simulator Sickness Questionnaire (SSQ) after performing functional assessment and rehabilitation training.

*mIMI*

The Intrinsic Motivation Inventory, published in 1989 to assess patients’ subjective experience, uses a 7-point Likert scale (1=strongly disagree, 7=strongly agree) and consists of 45 items.

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**Fig. 2.** Functional assessments and rehabilitation training modules of the CoTras Vision system (COTRAS).
Scores are calculated for each area of interest/enjoyment, perceived competence, effort/importance, pressure/tension, perceived choice, value/usefulness, and relatedness. We extracted 19 relevant questions (total score of 133) to identify the level of motivation in terms of participating in CoTras Vision.

**Patient Satisfaction Questionnaire**

To assess the level of satisfaction with CoTras Vision, 11 questions (total 55 points) rated on a 5-point Likert scale (1=very dissatisfied, 5=very satisfied) were administered. The questions concerned the description, screen brightness, touch accuracy, size, and speed of the presented modules, their convenience, and their side effects (Supplementary Table S1) [20].

**SSQ**

The SSQ published in 1993 measures cybersickness and is widely used to measure dizziness related to electronic devices. The CoTras Vision consists of a large touch screen with many modules with flickering, which is likely to result in cybersickness in some individuals [21]. Patients answered 16 questions after the intervention, rating each symptom on a scale from 0 to 3 (0=no symptoms, 3=severe symptoms). The collected scores were weighted to calculate the score for three major clusters: nausea, eye movement discomfort (oculomotor), and disorientation, for a total SSQ score. A higher total score indicates severe dizziness.

**Procedures**

Patients in this study underwent the following procedures. Initially, paper-and-pencil tests, including Albert's test and the Star cancellation test, were conducted. For these tests, the evaluation concluded when patients declared their completion, even if they did not perform them perfectly. Additionally, if a patient took more than 5 minutes to complete the tests, the evaluation was terminated. Subsequently, assessments using the CoTras Vision were carried out, also imposing a 5-minute time limit [9,22]. Following the assessment, rehabilitation training using the CoTras Vision was administered, incorporating the visual tracking, visual perception training, central peripheral integration, and digit selection modules. Each training session was allotted 1 minute, and a total of 3 sessions were conducted per module. The overall duration of the training was approximately 15–20 minutes. Surveys were conducted after both the evaluation and training. All procedures were administered by the same trained researchers across both assessments and training sessions.

**Statistical analysis**

Baseline demographics of patients (sex, age, stroke type, lesion side, and lesion location) were analyzed using descriptive statistics. To evaluate the agreement of functional assessment between CoTras Vision and the paper-and-pencil test, a Bland–Altman plot was used. We performed frequency analysis and descriptive statistics to analyze the results of the patient-reported questionnaires. IBM SPSS Statistics 27.0 (IBM Corp.) was used for all statistical analyses, and the level of statistical significance was set at 0.05.

**RESULTS**

Among the 12 patients enrolled in the study, two dropped out, and 10 completed the assessments and rehabilitation training. The baseline demographics of the patients are presented in Table 1. Of the 10 patients, 7 were males and 9 had ischemic

<table>
<thead>
<tr>
<th>No.</th>
<th>Sex</th>
<th>Age (yr)</th>
<th>Stroke type</th>
<th>Stroke onset (day)</th>
<th>Lesion side</th>
<th>Lesion area</th>
<th>MMSE-K</th>
<th>FMA (upper/lower)</th>
<th>MBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>55</td>
<td>Ischemic</td>
<td>16</td>
<td>Rt.</td>
<td>Lateral medullary</td>
<td>27</td>
<td>59/23</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>68</td>
<td>Ischemic</td>
<td>29</td>
<td>Rt.</td>
<td>BG and HT</td>
<td>25</td>
<td>2/18</td>
<td>55</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>53</td>
<td>Hemorrhage</td>
<td>7</td>
<td>Rt.</td>
<td>BG</td>
<td>28</td>
<td>65/34</td>
<td>92</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>52</td>
<td>Ischemic</td>
<td>20</td>
<td>Rt.</td>
<td>Multiple cerebral infarction</td>
<td>27</td>
<td>64/34</td>
<td>88</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>79</td>
<td>Ischemic</td>
<td>12</td>
<td>Rt.</td>
<td>Pons</td>
<td>21</td>
<td>50/24</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>79</td>
<td>Ischemic</td>
<td>19</td>
<td>Rt.</td>
<td>Midbrain, thalamus, cerebellum, and occipital lobe</td>
<td>26</td>
<td>65/33</td>
<td>80</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>74</td>
<td>Ischemic</td>
<td>23</td>
<td>Rt.</td>
<td>Multiple cerebral infarction</td>
<td>27</td>
<td>66/30</td>
<td>87</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>69</td>
<td>Ischemic</td>
<td>21</td>
<td>Lt.</td>
<td>PV and BG</td>
<td>28</td>
<td>6/4</td>
<td>31</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>61</td>
<td>Ischemic</td>
<td>12</td>
<td>Lt.</td>
<td>Paramedian pontine</td>
<td>27</td>
<td>66/15</td>
<td>74</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>59</td>
<td>Ischemic</td>
<td>12</td>
<td>Lt.</td>
<td>BG</td>
<td>25</td>
<td>14/27</td>
<td>45</td>
</tr>
</tbody>
</table>

MMSE-K, Korean version of Mini-Mental State Examination; FMA, Fugl-Meyer assessment; MBI, modified Barthel Index; F, female; M, male; Rt., right; Lt., left; BG, basal ganglia; HT, hypothalamus; PV, periventricular.
stroke. The mean ± standard deviation age was 64.9 ± 10.3 years.

The CoTras Vision exhibited good agreement with the paper-and-pencil test. The Bland–Altman plot revealed a mean difference of -0.3 ± 4.5, and the results of all patients except one fell within the 95% confidence interval in Albert’s test. The Star cancellation test also exhibited good agreement, with a mean difference of 0.3 ± 0.7, and the results of all 10 patients fell within the confidence interval (Fig. 3, Supplementary Table S2).

The mean mIMI score was 84.7 ± 30.6. The item with the highest score was item 1: “I enjoyed doing this training very much.” The item with the lowest score was item 19: “I did not put much energy into this.” (Supplementary Table S3). The mean score for the Patient Satisfaction Questionnaire was 40.5 ± 7.9 points. The item with the highest mean score (4.2 points) was item 3: “Understanding of the description displayed at the beginning of the module.” The size of the monitor, distance between the equipment and the patient, and convenience of use without any physical side effects (items 1, 2, and 11) exhibited the lowest mean score of 3.4 (Supplementary Table S4). The mean SSQ score was 34.0 ± 34.5. In terms of the total score, the extent of cybersickness was substantial in four patients (patient 1, 78.54; patient 2, 44.88; patient 4, 108.46; patient 9, 48.62; Fig. 4, Supplementary Table S5).

![Fig. 3. Bland–Altman plots of comparison between the CoTras Vision (COTRAS) and paper-and-pencil test. (A) Albert’s test. (B) Star cancellation test.](image)

![Fig. 4. Total and symptom cluster score of Simulator Sickness Questionnaire. (A) Total score. (B) Symptom cluster score.](image)
DISCUSSION

In this study, we developed CoTras Vision, a computer-based visuomotor integration system for patients with poststroke VFDs and spatial neglect. The overall validity, side effects, patient satisfaction, and usability of this system were assessed in the entire cohort of poststroke patients. Two functional assessments, Albert’s test and Star cancellation test, exhibited a high level of agreement with the CoTras Vision. The questionnaires for internal motivation and satisfaction revealed results that were above moderately positive. Although no serious side effects were observed, some patients complained of dizziness.

Existing functional assessments for spatial neglect using paper-and-pencil tests have necessitated usage of the same size of test paper to be placed on the desk and to be completed using a pen or pencil. Regarding the CoTras Vision system, the components of the original tests were faithfully reproduced, albeit on a larger screen size, and patients could use the touch function rather than a pen or pencil. The test needed to be completed on a screen at eye level rather than on a desk, which might have restricted its use by patients with weak upper limb strength. Despite these differences, the CoTras Vision system had high agreement with the original tests. The CoTras Vision system had several strengths. The assessment was conducted on a high-resolution display; therefore, the patient could have focused better during the test. The modules were designed for a computer and the same items could be implemented in alternative ways on the screen. This could potentially reduce the learning effect that may have occurred when the same test was taken by the same patient. Thus, if the reliability of the alternative test could be maintained, functional improvement in patients could be evaluated with higher precision. Furthermore, the size of the screen could be reduced by adjusting the resolution, and the height could be adjusted vertically. Therefore, this system has flexibility for use by children. Moreover, since it can be implemented on a web-based platform, the tests can be conducted remotely; we expect eventual widespread adoption of this system for tele-rehabilitation.

The mean mIMI score of 84.7±30.6 out of 133, which was markedly higher than the median value of 66.5, indicated that patients were sufficiently motivated to use the CoTras Vision system. Specifically, the high score for the item “I enjoyed doing this training very much” confirmed that patients were satisfied to perform the test and training even when they were not familiar with the equipment.

The mean satisfaction score was 40.5±7.9 out of 55, which was mostly positive. However, in line with previous studies about computer-based rehabilitation treatments, dissatisfaction with the size of the monitor, the distance from the monitor, and visual fatigue due to the brightness of the screen were also identified in this study [23].

Finally, the mean SSQ score was 34.0±34.5 out of 235.6. SSQ was originally proposed by Kennedy et al. [21] in 1993, and it has been widely used to assess sickness symptoms associated with medical devices. A total score of SSQ exceeding 20 is generally considered to be categorized as a “bad” simulator [24]. However, this severity classification has been criticized for being a potential overestimation, because the majority of the dataset of SSQ is derived from a military population [25]. All but one patient scored below 80, a relative low score compared to the total score of 235.6, which was not associated with severe cyber sickness. We conducted a detailed evaluation of scores for each question and analyzed the subjective responses in four patients with relatively high scores. This analysis revealed a tendency to complain of difficulties in visually focusing on the screen, which corresponded with responses to the satisfaction questionnaire.

The rehabilitation training modules of the CoTras Vision system were developed based on rehabilitative devices and software that yielded positive clinical outcomes in previous studies [11,26-28]. A representative rehabilitation training device is the Dynavision system [11,15]. The Dynavision system has 64 flashing physical buttons arranged radially on a 165×120 cm panel and is used by pressing buttons randomly or in a specific sequence within a given time limit. It is widely used to improve visual perception function and reaction rates in athletes, and its efficacy has been demonstrated in the treatment of visual perception disorders in patients who have had a stroke [2,11,29]. The rehabilitation training of the CoTras Vision system was similar to that of the Dynavision system, but a wider variety of training modules can and have been developed and implemented with the latter, and usage of a touch screen allows patient-customized treatment with higher levels of motivation. Another advantage is that the real-time feedback provided during training may increase the focus and invoke a sense of achievement in the patient.

Various therapeutic strategies have been considered for treating VFDs, including optical substitution, visual search or exploration training, restorative training, and blind spot stimulation [30]. Mueller et al. [31] reported significant improvements in
the detection of super-threshold stimuli in patients with VFDs caused by various central nervous system disorders following vision restoration therapy (NovaVision AG). This therapy involves patients focusing on a point in the center of the screen and responding every time they see light stimuli that appear elsewhere on the screen. The “visual perception training” and “central peripheral integration training” approaches in our study aligned with these approaches. Aimola et al. [32] demonstrated objective benefits in patients with homonymous VFD using unsupervised compensatory computer-based training. This intervention consists of a visual exploration task, in which patients try to find specific feature among the distractors, and a reading task, during which patients define a nonword target among the words. These training routines share similar treatment mechanisms with the “visual tracking” and “digit selection” approaches used in our study. Another study used a desktop computer and projector to show positive effects in patients experiencing poststroke neglect [33].

This study had some limitations. First, the patient population recruited may not have been representative of the target patient population for this system. CoTras Vision was specifically developed for evaluation and treatment of VFDs and hemineglect symptoms in poststroke patients. Nevertheless, our study included all stroke patients, irrespective of these symptoms, to assess its broader applicability. To use CoTras Vision in clinical practice, future studies are necessary to validate the effectiveness of its evaluation and treatment in poststroke patients who do have symptoms of VFDs and hemineglect. Second, the small sample size might not have been sufficient to compare its validity to that of the original tests. The CoTras Vision system was a computer-based assessment tool that had advantages in terms of patient data management and could provide reliable measurements in repeated tests. However, much larger sample sizes are required to prove its reliability. Third, the effect of rehabilitation training using the CoTras Vision system needs to be verified in patients with stroke. Our results indicated that patients demonstrate substantial motivation and minimal resistance when using the CoTras Vision system. Nevertheless, to corroborate its efficacy in the clinical setting, additional clinical trials are imperative.

In this study, we verified that the CoTras Vision system was feasible and safe in patients with stroke. Positive results in terms of motivation and satisfaction with the CoTras Vision system were confirmed by most of the patients. Further investigation is necessary in patients with specific symptoms of VFDs and hemineglect. Furthermore, additional randomized clinical trial is required to determine the clinical effects of rehabilitation training using the CoTras Vision system.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

FUNDING INFORMATION

This research was supported by a grant from the Daegu-Gyeongbuk Medical Innovation Foundation, funded by the Daegu Metropolitan City of the Republic of Korea (No. B-A-K-22-01).

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SUPPLEMENTARY MATERIALS

Supplementary materials can be found via https://doi.org/10.5535/arm.230028.

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Applying ICF Framework to Explore the Factors That Influence Quality of Life in Patients After Lung Surgery

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**Objective:** To explore the relationship between pulmonary function, physical activity, and health-related quality of life (QoL) in resected lung cancer patients based on the International Classification of Functioning, Disability, and Health (ICF) framework developed by the World Health Organization to describe health and health-related states.

**Methods:** A quantitative study was designed with postoperative lung cancer survivors to assess personal characteristics. We also assessed functional impairment related to the lung using forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV\textsubscript{1}), activity limitations using maximal oxygen consumption (VO\textsubscript{2max}), anaerobic threshold (AT) and 6-minute walking distance (6MWD), and participation restriction using the 36-item Short Form Health Survey V1 (SF-36). Data analyses were conducted using the multivariate method and SmartPLS to examine path coefficient among the measures.

**Results:** Forty-one patients were enrolled in this study. FVC and FEV\textsubscript{1} were poorly correlated with QoL, and 6MWD, AT, or VO\textsubscript{2max} were positively associated with QoL. AT or VO\textsubscript{2max} showed a significant (p<0.01) direct path with SF-36 in the ICF model. Although age and body mass index were not strongly correlated with QoL, these personal factors had a medium to large effect on perceived QoL.

**Conclusion:** Disability is a complex in patients with lung resection, and physical activity plays an important role in enabling participation. Improving VO\textsubscript{2max} and AT is needed to improve the QoL of resected lung cancer patients. We should also pay more attention to contextual factors that have a significant impact on social participation.

**Keywords:** Latent class analysis; Lung neoplasms; Quality of life; International Classification of Functioning, Disability and Health; Factors

**INTRODUCTION**

Much progress has been made in the diagnosis and treatment of non-small cell lung cancer in recent years, and prognosis has gradually improved correspondingly. For a significant number of patients, surgical resection is the preferred treatment. While
the survival rate after an operation is not satisfactory, more and more patients want to obtain prolonged postoperative survival [1] and a better quality of life (QoL) [2]. Therefore, exploring the factors that affect QoL in these patients is of great importance.

Lung resection has a significant short- and long-term impact on pulmonary function and oxygenation [3], and physical activity, measured by 6-minute walking distance (6MWD), has also been reported to decline after surgery [4]. And many symptoms, including dyspnea, emotions, pain, and side effects of treatment, may occur after lung resection. Lung resection is so invasive that it lowers QoL, especially in the early stages of surgical treatment [5]. Improving the QoL after surgery is one of the main goals of comprehensive treatment. Interestingly, many evidences showed that many aspects are involved to the QoL in various types of diseases. For instance, the previous study showed that peak oxygen uptake, 6MWD, and anxiety remained independent factors for QoL in patients with pulmonary arterial hypertension [6]. Engberg et al. [7] found that cardiorespiratory fitness (CRF) was positively associated with health-related QoL in females at risk for gestational diabetes. And Ha et al. [8] reported that exercise capacity was independently associated with QoL for lung cancer patients after postcurative intent treatment.

Because great number of factors affect patient’s health comprehensively including structural impairments, functional limitations, participation restrictions and contextual factors, it is crucial to identify risk factors that may deteriorate a patient’s health status. The World Health Organization’s International Classification of Functioning, Disability and Health (WHO ICF) model provides a coherent view of different aspects of health from biological, individual and social perspectives [10], as shown in Fig. 1. As an analysis framework, the interplay between these factors in the ICF model is important for characterizing the disability and providing rehabilitation [11]. To our knowledge, the association between patients’ physical activities and QoL according to the ICF model has not been studied.

Various factors influence QoL in patients with lung cancer, including malnutrition [12], social support [13], psychosocial factors [14], and physical activity [15]. Data indicate that lung cancer patients experience compromised QoL. Therefore, understanding the factors that determine QoL for patients after lung resection is crucial in enhancing prevention programs and treatment strategies. In this study, we propose an ICF-based model, illustrated in Fig. 2, to explore the associations between pulmonary function, physical activity, personal factors, and health condition.

![Fig. 1. International Classification of Functioning, Disability and Health categorization of outcome measures used in this study.](image1)

![Fig. 2. The hypothetical model based on International Classification of Functioning, Disability and Health framework. FVC, forced vital capacity; FEV$_1$, forced expiratory volume at 1 second; 6MWD, 6-minute walking distance; AT, anaerobic threshold; VO$_{2\text{max}}$, maximal oxygen consumption; SF-36, the 36-item Short Form Health Survey V1; BMI, body mass index.](image2)
QoL using the ICF model and to assess their impact on QoL of patients after lung resection.

**METHODS**

**Ethics**

Ethical approval has been obtained from the Ethical Committee of Guangdong Provincial People’s Hospital (2012124H(R2)). The clinical trial had been registered in the Chinese Clinical Trials Registry (ChiCTR-TRC-13003400). This study was conducted in accordance with the declaration of Helsinki ethical principles for human experimentation and all patients gave their informed consent to participate in the study.

**Study design**

A quantitative study was designed and Fig. 3 presents the flowchart of the study. Patients who underwent lobectomy were recruited according to criteria for non-small cell lung cancer staged T1, T2, and T3a without chronic obstructive pulmonary disease. Exclusion factors included: Stage T3b and T4 non-small cell lung cancer, patients with serious chronic diseases (i.e., coronary artery disease, heart failure, atrial fibrillation, hypertension, osteoporosis, infections), refused to participate in this study. Each patient had a routine full clinical assessment prior to inclusion, and all patients included in this study provided written informed consent before data collection.

Data including age, sex, and body mass index (BMI) were recorded, and assessments including forced vital capacity (FVC), FEV₁, 6MWD, anaerobic threshold (AT), maximal oxygen consumption (VO₂max), and the 36-item Short Form Health Survey V1 (SF-36) were performed one month after lung resection. Data were collected from January 2014 to December 2017. The same therapists conducted all evaluations throughout duration of the study. Data collection and analysis were not carried out by the same persons who completed the assessment.

According to the results of preliminary experiment, with power of 0.9, alpha of 0.05, ρ₀=0, and ρ=0.5. Sample size was calculated using a formula for correlation study with PASS20.0 software (NCSS, LLC), and the total sample size is 37. To compensate non-compliance among subjects, the sample size was increased (+10%) to 41 patients.

**Observed variables**

Pulmonary volumes including FVC and FEV₁ were measured using a spirometer (Electgraph HI-101; CHEST), and corrected for temperature and barometric pressure, according to the American Thoracic Society recommendations [16]. Each patient performed at least three trials and the best results were used for analysis.

Physical activity was determined by 6MWD [17]. 6MWD was carried out under the same conditions. Patients were instructed to walk at their fastest pace to cover the longest possible distance over 6 minutes. The longest walk was taken to represent the value.

Before the cardiopulmonary exercise test, a physician examined the patients beforehand to ensure their suitability for the test. We assessed CRF by VO₂max and AT in incremental (30 W/3 min) cycle ergometer exercise (METAMAX 3B; CORTEX) until patient fatigue or dyspnea by pointing to a score on Borg scale category ratio 10. VO₂max was determined as the highest 1-minute average value and was normalized for body mass (mL/kg/min).

Health-related QoL was evaluated with SF-36 [18]. The survey is a valid and reliable 36-item questionnaire that is widely used to measure QoL. It yields two summary scores of physical (physical functioning, role-physical, bodily pain, and general health) and mental (vitality, social functioning, mental health, and role-emotional) health. Scales range from 0 to 100, with 0

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**Fig. 3.** The summary of workflow in this study. SF-36, the 36-item Short Form Health Survey V1; PLS-SEM, partial least squares structural equation modeling.
indicating the worst situation and 100 indicating the best situation in each domain.

Statistical analysis

Data were expressed through descriptive and inferential statistical analysis. Firstly, we examined whether the variables were normally distributed with the Anderson-darling test, then we used Spearman’s correlation coefficients for non-normally distributed variables. For normally distributed variables, we used Pearson’s correlation coefficients. The dependent variables were SF-36 total score, and the independent variables were FEV$_1$, FVC, 6MWD, VO$_{2\text{max}}$, AT, and personal factors including age, sex, and BMI. The Statistical Package for Social Sciences (IBM SPSS 20.0; IBM Corp.) was used. Secondly, a structural model was estimated and structural equation modeling was used to examine the path coefficient between the measures, and the proposed hypotheses were confirmed. To test the proposed model, we adopt partial least squares structural equation modeling (PLS-SEM) using SmartPLS software (version 4) due to the small sample size. And the sample size of the PLS-SEM was determined in accordance with the principle that the sample size should be a minimum of 10 times the greater of: (1) the largest number of formative indicators employed to measure a single construct, or (2) the largest number of structural paths directed towards a specific construct within the structural model [19].

In our study, the largest number of structural paths directed towards a specific construct within the structural model were three, and the total sample size was at least 30. Hence, the designated sample size in this study was 41 which was sufficient to perform the PLS-SEM. When performing the confirmatory factor analysis, we ensured the original model of four factors and 8 items with factor loadings above 0.50, the composite reliability (CR) and convergent validity (average variance extracted, AVE) ranged from 0.6 to 1.00 and higher than 0.5, respectively [20].

In our study, we interrogated the robustness of the model using blindfolding to obtain cross-validated redundancy measures for each construct and using the bootstrapping procedure with 5,000 re-samples to determine the significance level of weights, factor loadings, and path coefficients [20]. A $p$-value of $<0.05$ was considered statistically significant.

RESULTS

Clinical characteristics

Forty-one patients were enrolled in this study and the complete data were included in the analysis. Among these participants, the TNM classification of lung cancers was as follows: 26 stages 1, 11 stages 2, and 4 stages 3a. The types of lung cancer cells were as follows: 25 adenocarcinomas, 13 squamous carcinomas, and 3 others. The median age was 62 years (61.73±10.89 years), and 51.20% (21 out of 41) were male. The median BMI was 22. Table 1 summarized the characteristics, QoL, FVC, FEV$_1$, 6MWD, AT, and VO$_{2\text{max}}$ of the patients.

Correlation matrix

In the study, the values of sex, BMI, 6MWD, VO$_{2\text{max}}$ and SF-36 had normal distribution. In relation to the SF-36 total score, Table 2 showed a significant linear correlation was detected between 6MWD ($r=0.317$, $p=0.044$), AT ($r=0.442$, $p=0.004$), and VO$_{2\text{max}}$ ($r=0.344$, $p=0.028$). SF-36 total score was poorly correlated with FVC ($r=0.144$, $p=0.370$), FEV$_1$ ($r=0.251$, $p=0.114$), BMI ($r=0.187$, $p=0.242$), age ($r=0.216$, $p=0.176$), and sex ($r=-0.054$, $p=0.739$).

Evaluation of the models

A reflective modeling approach was employed to test the hypotheses. CR and the AVE were used to assess the convergence of observed variables. As shown in Fig. 4, all items exceeded the 0.62 loading threshold, with CR ranging from 0.6 to 1.0 and higher than 0.5 with AVE. To establish discriminant validity, we selected the heterotrait-monotrait ratio, with all values in this study below 0.597 (Table 3), meeting the recommended cut-off of 0.85 [20]. In addition, collinearity was examined to

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value (n=41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (male/female)</td>
<td>51.20/48.80</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>61.73±10.89</td>
</tr>
<tr>
<td>Body mass index</td>
<td>21.56±2.95</td>
</tr>
<tr>
<td>Smoking history (no/yes)</td>
<td>73.17/26.83</td>
</tr>
<tr>
<td>Histological type (Ad/Sc/other)</td>
<td>60.97/31.70/7.33</td>
</tr>
<tr>
<td>Pathological stage (I/II/III)</td>
<td>63.41/26.83/9.76</td>
</tr>
<tr>
<td>Maximal oxygen consumption</td>
<td>17.29±4.01</td>
</tr>
<tr>
<td>Anaerobic threshold</td>
<td>12.02±3.67</td>
</tr>
<tr>
<td>6-Minute walking distance</td>
<td>496.3±69.95</td>
</tr>
<tr>
<td>Forced vital capacity</td>
<td>2.11±0.65</td>
</tr>
<tr>
<td>Forced expiratory volume at 1 second</td>
<td>1.76±0.53</td>
</tr>
<tr>
<td>Health-related quality of life</td>
<td>50.74±12.33</td>
</tr>
<tr>
<td>Physical component summary</td>
<td>21.52±7.59</td>
</tr>
<tr>
<td>Mental component summary</td>
<td>27.19±7.42</td>
</tr>
</tbody>
</table>

Values are presented as percent only or mean±standard deviation. Ad, adenocarcinoma; Sc, squamous carcinoma.
processes ensure unbiased regression results, and the variance inflation factors (VIFs) for inner model paths were evaluated. The results revealed that VIF values ranged from 1.0 to 1.15, well below the recommended threshold of 5. With respect to model fit, the standardized root mean residual and normed fit index had values of 0.057 and 0.933, respectively, which were both within the recommended range. These data indicated that the constructs met the required standards for the present study, allowing us to adequately test the research hypotheses (Table 3).

As shown in Table 4, the path linking personal factors and physical activities to perceived SF-36 was positive and statistically significant, and the path linking FVC, and FEV₁ to SF-36 was not positive and statistically insignificant. The $R^2$ value for SF-36 is 0.360 which means that 36.0% of the changes in QoL

| Table 2. Correlation coefficients of sex, BMI, age, FEV₁, FVC, AT, VO₂max, and 6MWD with health-related quality of life (SF-36) |
|---|---|---|---|---|---|---|---|---|
| Domains (SF-36) | FVC | FEV₁ | Sex | Age | AT | 6MWD | BMI | VO₂max |
| Physical health | R=-0.218, p=0.171 | R=0.313, p=0.046 | R=-0.068, p=0.672 | R=-0.100, p=0.533 | R=0.423, p=0.006 | R=0.304, p=0.053 | R=0.156, p=0.329 | R=0.282, p=0.074 |
| Mental health | R=0.048, p=0.766 | R=0.190, p=0.234 | R=-0.113, p=0.480 | R=-0.277, p=0.08 | R=0.425, p=0.006 | R=0.329, p=0.036 | R=0.186, p=0.244 | R=0.390, p=0.012 |
| Summary | R=0.144, p=0.370 | R=0.251, p=0.011 | R=-0.054, p=0.739 | R=-0.216, p=0.176 | R=0.442, p=0.004 | R=0.317, p=0.044 | R=0.187, p=0.242 | R=0.344, p=0.028 |

BMI, body mass index; FEV₁, forced expiratory volume at 1 second; FVC, forced vital capacity; AT, anaerobic threshold; VO₂max, maximal oxygen consumption; 6MWD, 6-minute walking distance; SF-36, the 36-item Short Form Health Survey V1.

| Table 3. Convergent validity, discriminant validity, and collinearity statistics |
|---|---|---|---|---|---|---|---|---|---|
| | CR | AVE | Structures/function | Activities | Personal factors | Structures/function | Activities | Participation |
| Structures/function | 0.974 | 0.950 | - | - | - | - | 1.013 | 1.134 |
| Activities | 0.830 | 0.620 | 0.358 | - | - | - | - | 1.150 |
| Participation | - | - | 0.287 | 0.553 | - | - | - | - |
| Personal factors | 0.712 | 0.555 | 0.597 | 0.454 | 0.230 | 1.000 | 1.013 | 1.032 |

CR, composite reliability; AVE, average variance extracted; VIF, variance inflation factor.
were due to pulmonary function, physical activity, and personal factors in the model (Fig. 4). In general, the effect of a latent predictor variable is small at the structural level if $f^2$ is 0.02, medium if $f^2$ is 0.15, and large if $f^2$ is 0.35 [20]. We found that physical activity ($f^2=0.292$) and personal factors ($f^2=0.197$) had medium to large effect sizes on perceived QoL, while pulmonary function had no effect sizes on perceived QoL in patients with lung resection (Table 5).

**DISCUSSION**

This study examined the relationship between FEV$_1$, FVC, 6MWD, personal factors, and health-related QoL in patients with lung resection. Our results showed that FVC and FEV$_1$ were poorly correlated with QoL, and 6MWD, AT, or VO$_{2\text{max}}$ were positively associated with QoL. Our findings also showed that pulmonary function, physical activity, age, and BMI took charge of 36.0% of changes in perceived QoL in the ICF model. Although age and BMI were not strongly correlated with QoL, the personal factors had a medium to large effect on perceived QoL.

Many pieces of evidence showed that lung resection had a significant impact on respiratory function, and the deficits may reduce the patients’ QoL [3,5]. However, Brunelli et al. [9] found that QoL had a poor correlation with FEV$_1$ and carbon monoxide lung diffusion capacity. In this study, we also showed that FVC and FEV$_1$ were not related to QoL. These results indicated that FVC and FEV$_1$ affected only a few functioning scales and could not be taken as surrogate for QoL evaluation [9]. Because few direct effects of FVC and FEV$_1$ on QoL were observed in our study, pulmonary function-enhancing intervention may play a limited role in improving QoL in resected lung cancer patients.

Lung cancer survivors always experience QoL impairments, and engagement in physical activity is associated with better QoL. Also, physical activity was independently associated with QoL in lung cancer patients with postcurative-intent treatment [8]. We also found that 6MWD was associated with QoL, but the significance level was $p=0.045$. However, 6MWD recovery in elderly patients after lung cancer surgery was not related to their health-related QoL recoveries [4]. One possible reason for inconsistent results is that the effect of 6MWD on QoL is indirect. CRF is primarily determined by aerobic physical activity, and is strongly associated with the physical dimensions of health-related QoL. In our study, CRF (6MWD, AT, and VO$_{2\text{max}}$) was positively associated with QoL, and AT or VO$_{2\text{max}}$ were also highlighted as predictors. The results indicated that physical activity had a significant impact on improving QoL in patients with lung resection.

In the clinic, QoL in resected lung cancer patients was poor.

<p>| Table 4. Summary of estimates for hypothesized structural model |
|-------------------|-------------------|-------------------|-------------------|-------------------|</p>
<table>
<thead>
<tr>
<th>Path</th>
<th>Standardized path coefficients (mean±standard error)</th>
<th>Sig.</th>
<th>Unstandardized path coefficients (mean±standard error)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structures/function</td>
<td>Activities</td>
<td>0.315±0.024</td>
<td>0.041</td>
<td>2.453±0.262</td>
</tr>
<tr>
<td></td>
<td>Participation</td>
<td>0.169±0.020</td>
<td>0.183</td>
<td>3.697±0.447</td>
</tr>
<tr>
<td>Activities</td>
<td>Participation</td>
<td>0.474±0.018</td>
<td>0.000</td>
<td>1.420±0.080</td>
</tr>
<tr>
<td>Personal factors</td>
<td>Structures/function</td>
<td>-0.101±0.035</td>
<td>0.608</td>
<td>-0.020±0.080</td>
</tr>
<tr>
<td></td>
<td>Activities</td>
<td>-0.093±0.032</td>
<td>0.543</td>
<td>-0.121±0.050</td>
</tr>
<tr>
<td></td>
<td>Participation</td>
<td>0.368±0.025</td>
<td>0.027</td>
<td>1.178±0.106</td>
</tr>
</tbody>
</table>

Structures/function: forced vital capacity; forced expiratory volume at 1 second. Activities: 6-minute walking distance; anaerobic threshold; maximal oxygen consumption. Participation: the 36-item Short Form Health Survey V1. Personal factors: age, body mass index.

<p>| Table 5. Results of effect size $f^2$ analysis |
|-------------------|-------------------|-------------------|-------------------|-------------------|</p>
<table>
<thead>
<tr>
<th>Dependent construct</th>
<th>Independent construct</th>
<th>$R^2$</th>
<th>$f^2$</th>
<th>Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structures/function</td>
<td>Personal factors</td>
<td>0.013</td>
<td>0.013</td>
<td>-</td>
</tr>
<tr>
<td>Activities</td>
<td>Structures/function</td>
<td>0.130</td>
<td>0.119</td>
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<tr>
<td></td>
<td>Personal factors</td>
<td>0.018</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Participation</td>
<td>Structures/function</td>
<td>0.360</td>
<td>0.041</td>
<td>Small</td>
</tr>
<tr>
<td></td>
<td>Activities</td>
<td>0.292</td>
<td>Medium to large</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Personal factors</td>
<td>0.197</td>
<td>Medium to large</td>
<td></td>
</tr>
</tbody>
</table>

Structures/function: forced vital capacity; forced expiratory volume at 1 second. Activities: 6-minute walking distance; anaerobic threshold; maximal oxygen consumption. Participation: the 36-item Short Form Health Survey V1. Personal factors: age, body mass index.
Poor QoL means difficulty for these types of patients dealing with a range of deficits or limitations related to cognitive, psychosocial, physical, sensory functioning, and other aspects of performance [21]. From a statistical point of view, in relation to the disability process, contextual factors can act as independent factors, confounding factors, moderating factors, and mediating factors [22]. We found that personal factors (age and BMI) had a direct effect on QoL in this study. Noting that only 36.0% of perceived QoL changes were associated with pulmonary function, physical activity, age, and BMI. Thus, the improving QoL program for lung resection patients focuses not only on how to improve physical activity, but also on other impact factors such as environmental factors and personal factors.

With regard to the limitations of this study, it was a single-center study. Meanwhile, some other factors that could affect QoL in resected lung cancer patients were not included in our structural equation modeling, such as family support, economic level, and environmental impact. In the future, large-scale observational studies involving sufficient patients and effect factors are needed.

In conclusion, disability is a complex in patients with lung resection and encompasses a prominent role of physical activity in predicting participation. Improving VO$_{2\text{max}}$ is needed to improve the QoL of resected lung cancer patients. We should also pay more attention to contextual factors that have a significant impact on social participation.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

FUNDING INFORMATION

This work was supported by National Natural Science Foundation of China (No. 81972142) and Guangdong Medical Science and Technology Research Foundation (No. A2022512).

AUTHOR CONTRIBUTION

Conceptualization: Li X, Zhang M. Methodology: Chen Y, Liu S. Formal analysis: Li X, Chen Y, Liu S. Funding acquisition: Li X. Project administration: Li X, Zhang M. Supervision: Zhang M. Writing – original draft: Li X. Writing – review and editing: Li X, Zhang M. Approval of final manuscript: all authors.

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INTRODUCTION

Humans perform everyday activities in a variety of situations while simultaneously using their motor, cognitive, and sensory functions, therefore they cannot be performed as a single task [1]. As a result, human activities consist of several tasks or dual tasks [2]. Dual tasking, or the action of managing several, concurrently tasks, is prevalent throughout daily life. In particular, the bulk of our mobility tasks (such as standing, walking, stepping, etc.) are performed while being interrupted by another motor and/or cognition task [3]. One characteristic of dual task is that performance on one or both tasks decline when carried out simultaneously [4]. These variations in performance are known as dual task effects (DTEs), when utilizing dual task, you may prioritize one job over another. This might result in people prioritizing mobility or cognitive activities differently [5], leading to strategies called “posture first” or “posture second” in the context of mobility [3]. Cognitive functions are skills that are rooted in the brain and enable individuals to perform tasks of varying levels of complexity, which are essential in everyday life [6].

Measuring walking speed is an appropriate and reliable way to assess and monitor functional status and overall health in various populations and overall it is a sensitive measure [7] to record the level of functional status.

In both males and females, muscle performance is greatly influenced by the level of muscle strength, which is a crucial factor...
Several factors play a role in determining muscle performance, including physical build, age, height, and sex. Compared to females, males typically have greater physical strength, possibly due to having a higher muscle mass and lower body fat in addition to females’ lower testosterone production resulting in lower muscular volume, and the influence of estrogen leading to a higher percentage of fat mass, it is impossible for females to perform at the same level as their male counterparts.

This study aims to explore how sex impacts dual task performance by examining the cognitive and motor abilities of individual’s male and female participants during a dual task paradigm (i.e., the ability to generate muscular strength and perform physical movements while engaging in a cognitive activity at the same time). Comprehending the correlation between sex and dual task performance is important for a variety of real-world activities that require multitasking, such as driving, where individuals need to be able to perform multiple tasks simultaneously while maintaining attention and focus.

Research suggests that dual task performance can be improved with practice and training. However, it is important to note that there are limits to how much an individual can multitask effectively. If sex differences in dual task performance do exist, this knowledge could help inform the development of interventions or training programs that target these differences and improve overall performance. For example, some studies have found that females may perform better on dual task paradigms by combination of walking and engaging in a cognitive task simultaneously compared to males. Other studies have found there are no notable variations between sexes in dual task performance.

Elderly males exhibited greater postural instability compared to their female counterparts under dual task conditions. A different research found that gait measures in older females show a greater degree of variation compared with males. Falls are a significant public health concern, particularly among older adults. Prior research has indicated that dual task performance may be a predictor of fall risk in older adults. By investigating the effect of sex on dual task performance in adults, this study may provide insights into potential sex-specific fall risk factors and inform the development of targeted interventions to reduce fall risk in adults.

METHODS

Participants
During the period between July and September of 2023, a research study was conducted involving 67 non-athlete participants, consisting of 37 females and 30 males from Jouf University students aged between 20 and 35 years. The research ethic committee at Qurayyat Health Affairs approved the study (No. H-13-S-071) and the ClinicalTrials was registered under ID (NCT05912530). The study had specific inclusion criteria, which included having a body mass index (BMI) between 18 and 25 kg/m², normal range of motion at the time of the test, and not taking any medications or having any health issues that could affect their physical ability. Participants with musculoskeletal injuries to the leg, cognitive impairments, history of surgery, cardiovascular conditions, or any other health issue that could impact their physical ability were excluded. The participants were given information that their involvement was optional and confidential, and they gave their consent by signing. No reward or benefit was offered for their participation.

Instrumentation
The System 4-Pro Isokinetic Strength Dynamometer (Biodex) used to measure muscle torque for the knee extension. The dynamometer is a reliable and safe method that provides valid measurements. In order to train and test various muscle groups, the use of thigh, trunk, and dorsal bands was employed to provide support for the thigh, trunk, and foot while measuring angular position, torque, and velocities. The maximum force of the concentric knee extension muscles during isokinetic movement at an angular velocity of 60°/s was determined, and the peak torque (PT) was calculated by dividing the PT by the body weight (BW) ratio. Average speed was measured using the OneStep app on an iPhone 12 pro mobile during a 45 seconds walking test. To assess functional mobility performance, speed and torque were measured in both single and dual-task situations, with cognitive tasks consisting of subtracting 3 from a number that has been chosen at random, repeatedly between 100 and 150 (Fig. 1).

Test procedure
An explanation was given to the participants about testing procedures before the tests were administered, the participants in the dual-task group were told to perform both tasks at the same time without giving preference to either one. Single and dual-task measurements were carried out in a random sequence to prevent any potential issues brought on by the same order of measurements. Participants completed a questionnaire that is filled out by the individual themselves about social and demo-
graphic characteristics. The assessment was conducted in both single-task and dual-task situations. In a single data collecting session, which included a 45 seconds walking test was conducted, according to the participant’s velocity, single muscle torque production was done for a single motor task. PT/BW values have been recorded as measures of muscle motor performance. Single cognitive task were done through instruction to participant to count down from a random number between 100 and 150 in intervals of three for a duration of 45 seconds in a comfortably seated and quiet environment. The number of answers given and the number of correct ones were counted, and then the rate of correct responses (RCRs) per second was calculated using the formula:

$$ \text{RCR} = \frac{\text{correct answers}}{\text{total time}} \times \frac{\text{correct answers}}{\text{total answers}} $$

Dual-task condition of 45 seconds walking test and cognitive task through a combination between the both activities. The speed was measured as a motor performance indicator during a dual task. On the other hand, RCR was calculated as the total number of responses and the number are used as indicators of cognitive performance in a dual task. The same procedure was done by a combination between the motor torque and cognitive task. Following every single and dual-task situation, a break was provided, and individuals were instructed to complete each mobility task at a comfortable speed of their choosing. These three tests gave us three values for cognitive performance (single- and dual-task with walking speed, dual task with muscle torque production), two for functional performance (single and dual average speed), and two for muscle force production. These values were used to determine the motor and cognitive dual-task cost (DTC) values using the following formulas [4]:

$$ \text{Average speed DTC} (%) = \frac{\text{dual task average speed} - \text{single task average speed}}{\text{single average speed}} \times 100 $$

$$ \text{Muscle force production test DTC} (%) \text{ motor} = \frac{\text{dual task PT/BW} - \text{single task PT/BW}}{\text{single task PT/BW}} \times 100 $$

$$ \text{Cognitive} = \frac{\text{dual task RCR} - \text{single task RCR}}{\text{single task RCR}} \times 100 $$

**Sample size calculation**

In order to avoid type II error, the researchers calculated the sample size prior to conducting the experiment. The calculations were performed using G*Power software ver. 3.1.9.7. with $\alpha=0.05$, $\beta=0.2$, and an effect size of 0.40. The effect size for the impact of dual task on sex was determined based on previous work by Hollman et al. [12]. The required sample size was determined to be 66. To account for the drop-off, the sample size was expanded to 69 participants.

**RESULTS**

The IBM SPSS Statistics ver. 25 (IBM Corp.) was used to conduct the statistical analysis. Descriptive statistics, including mean, standard deviation, and frequencies, were computed. A significance level of $p<0.05$ was used to determine statistical significance.

The comparison between males and females for age and BMI was done using an independent test. The normal distribution of data was checked using the Shapiro–Wilk test, and the homogeneity between groups was tested using Levene’s test for
homogeneity of variances. The effect of sex and task on cognition was investigated by mixed model ANOVA. Paired t-test was conducted for comparison of torque and speed between single and dual tasks. ANCOVA was conducted for comparison of dual task torque and speed between males and females. Unpaired t-test was conducted for comparison of DTC in muscle torque production, DTC in cognition during muscle torque production, speed-DTC and cognitive-DTC during speed measurement between males and females.

Subject characteristics
In this study, there were a total of sixty-seven participants, with thirty-seven being females and thirty being males. The subjects had an average age of 21.25 years and an average BMI of 23.99 kg/m². Table 1 provided information on the characteristics of the male and female participants. It was found that there were no significant differences in age and BMI between males and females (p>0.05).

Effect of sex and task on cognition
There was no significant interaction of sex and task (F=2.17, p=0.12), there was a significant main effect of task (F=3.5, p=0.03) and there was no significant main effect of sex (F=0.01, p=0.91).

There was a significant increase in cognition at single task compared with that at dual task torque in males (p<0.05) while there was no significant difference in females (p>0.05).

There was no significant difference in cognition between single and dual task speed and between dual task torque and dual task speed in males and females (p>0.05).

There was no significant difference in cognition at single task, dual task torque and dual task speed between males and females (p>0.05; Table 2).

Effect of task on torque and speed
There was a significant decrease in torque at dual task compared with that at single task in males and females (p<0.001). There was a significant decrease in speed at dual task compared with that at single task in males (p<0.05) and females (p<0.001; Table 3).

Effect of sex on torque and speed at dual task
Dual task torque and speed of males and females were adjusted by the single task torque and speed to compensate for sex difference.

There was a significant decrease in torque and speed of females at dual task compared with that of males (p<0.01; Table 4).

Effect of sex on DTC in muscle force production, DTC in cognition during muscle force production, DTC in speed and DTC in cognition during speed measurement
There was a significant decrease in DTC in muscle force production of females compared with that of males (p<0.01) while there was a significant increase in DTC in cognition during muscle force production of females compared with that of males (p<0.001; Table 5).

There was a significant decrease in DTC in speed of females compared with that of males (p<0.001) while there was a significant increase in DTC in cognition during speed measurement of females compared with that of males (p<0.001; Table 5, Fig. 2).

Table 1. Subject characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Male</th>
<th>Female</th>
<th>Mean difference</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>21.60±1.92</td>
<td>20.97±1.25</td>
<td>0.63</td>
<td>1.61</td>
<td>0.11</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>24.63±4.44</td>
<td>23.46±3.61</td>
<td>1.17</td>
<td>1.19</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.

Table 2. Mean cognition at single task, dual task torque and dual task speed of males and females

<table>
<thead>
<tr>
<th>Cognition</th>
<th>Single task</th>
<th>Dual task (torque)</th>
<th>Dual task (speed)</th>
<th>MD (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single vs. dual-task torque</td>
<td>Single vs. dual-task speed</td>
<td>Dual-task torque vs. dual-task speed</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>0.39±0.14</td>
<td>0.33±0.17</td>
<td>0.34±0.20</td>
<td>0.06 (0.02)</td>
</tr>
<tr>
<td>Female</td>
<td>0.35±0.16</td>
<td>0.34±0.12</td>
<td>0.36±0.15</td>
<td>0.01 (&gt;0.99)</td>
</tr>
<tr>
<td>MD</td>
<td>0.04</td>
<td>-0.01</td>
<td>-0.02</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation. MD, mean difference.
DISCUSSION

The goal of this research was to examine how sex impacts dual-task abilities in young adults, specifically in terms of motor torque, cognitive tasks, and walking speed. Additionally, the study aimed to analyze the combined impact of cognitive and motor performance on DTCs. The focus was on observing changes in dual-task performance while engaging in various cognitive tasks.

The findings of this study suggest that there are no discernible cognitive task differences between males and females during single task, dual task with torque production, and dual walking which contradict the result of Almajid and Keshner [16]. The study findings indicated significant cognitive performance differences between males and females during both sitting and Timed Up and Go Tests (TUGs). Specifically, these differences were observed in terms of the quantity of accurate answers and mistakes made during cognitive assignments. Previous research has consistently reported that females tend to outperform males in verbal fluency and memory tasks, while males tend to outperform females in mental calculation tasks [17].

According to the study results, females experienced a notable decrease in speed when performing dual tasks, while there was no significant difference in speed between males. This is consistent with the findings of Lundin-Olsson et al. [18], who found that performing a cognitive task along with a physical activity can impede motor performance and increase the falling risk but this finding contradict with the results of Almajid and Keshner [16], who observed no difference in spatiotemporal measures or DTC between healthy young females and males while performing the TUG this may be return back to the fact that all subjects participated in this study were Arabs which may have played a role in the contradiction of the results to previous studies which conducted on American females and males. It is plausible that cultural differences in gait performance should be taken into account.

The study revealed females experienced a greater decline in motor performance, specifically muscle force production and speed, during dual tasks compared to males. On the other hand, males had worse cognitive performance during dual tasks compared to females which accept the theory of Clark [19] once the demands on attention of any two activities beyond overall attention capacity, the performance on the motor task, cognitive task, or both could be impaired in comparison to single-task performance. Interestingly, new research suggests that sex may influence prioritizing during mobility tasks. For example,

**Table 3.** Mean torque and speed at single task and dual task of males and females

<table>
<thead>
<tr>
<th></th>
<th>Single task</th>
<th>Dual task</th>
<th>Mean difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>117.72±48.97</td>
<td>89.83±39.03</td>
<td>27.89</td>
<td>0.001</td>
</tr>
<tr>
<td>Female</td>
<td>65.95±42.94</td>
<td>38.75±29.13</td>
<td>26.84</td>
<td>0.001</td>
</tr>
<tr>
<td>Speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>4.22±0.78</td>
<td>4.02±0.75</td>
<td>0.20</td>
<td>0.02</td>
</tr>
<tr>
<td>Female</td>
<td>3.87±0.48</td>
<td>3.38±0.68</td>
<td>0.48</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.

**Table 4.** Adjusted mean of dual torque and speed of males and females

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Mean difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque</td>
<td>72.52±3.97</td>
<td>52.78±3.52</td>
<td>19.74</td>
<td>0.001</td>
</tr>
<tr>
<td>Speed</td>
<td>3.85±0.08</td>
<td>3.53±0.07</td>
<td>0.32</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.

**Table 5.** Mean TQ-DTC motor, TQ-DTC cognitive, speed-DTC motor, and speed-DTC cognitive of males and females

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Mean difference</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TQ-DTC motor</td>
<td>-28.06±7.12</td>
<td>-33.98±9.95</td>
<td>5.92</td>
<td>0.008</td>
</tr>
<tr>
<td>TQ-DTC cognitive</td>
<td>-15.38±3.01</td>
<td>28.18±4.81</td>
<td>-43.56</td>
<td>0.001</td>
</tr>
<tr>
<td>Speed-DTC motor</td>
<td>-7.64±4.66</td>
<td>-16.19±5.95</td>
<td>8.55</td>
<td>0.001</td>
</tr>
<tr>
<td>Speed-DTC cognitive</td>
<td>-22.01±9.37</td>
<td>13.82±6.79</td>
<td>-35.83</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.

TQ-DTC motor, dual task cost with muscle force production; TQ-DTC cognitive, dual task cost with cognitive; speed-DTC motor, dual task cost with speed difference; speed-DTC cognitive, dual task cost with cognitive difference.

**Fig. 2.** Mean dual task cost with muscle force production (TQ-DTC motor), dual task cost with cognitive (TQ-DTC cognitive), dual task cost with speed difference (speed-DTC motor), and dual task cost with cognitive difference (speed-DTC cognitive) of males and females.
Agmon et al. [20] was found that females have higher motor DTE but lower cognitive DTE than males, and that sex affects the impact of personality on DTE. However, two smaller studies showed that there was no difference in DTE for cognitive and gait tasks between sexes, although males seemed to have more variety in gait than females during dual-task walking [12].

Stoet et al. [21] conducted a study that assessed the multitasking ability of both males and females in a realistic setting. Their results revealed that females performed better than males in a task that measures high-level cognitive skills, including planning, monitoring, and inhibition. These findings support the idea that posture may be more important for males than females in multitasking situations.

During a cognitive activity without priority, both males and females reduced their walking speed compared to normal walking which partially contradict our result. Females are more adaptable and responsive to the task instructions, while males’ gait speed is less affected. Although sex differences have been observed during other dual-task activities this study is the first to confirm sex variations in dual-task effects on gait [12].

On the other hand, these results also highlight differences in how males and females behave while using a cellphone while driving. Specifically, the study found that females had significantly longer brake response times and reduced stopping precision when distracted by their phone. However, when evaluated without the distraction, females exhibited faster brake response times and greater accuracy compared to males. This suggests that females prioritize cognition over motor performance, while males prioritize motor performance over cognition. These findings align with the “females follow the posture second theory” and the “males posture first theory” [22].

It has been shown that the difficulty to sustain a conversation during walking (“stop walking when talking”) is a predictor of future falls in older individuals [23]. Recently, a greater number of researches have recently studied the dual-tasking paradigm, as the first trials undertaken provided positive findings in the dual task’s capacity to be a clinical indicator of impaired cognition [24-26], fall risk [26-28] and frailty state [29,30] in elderly individuals. de Barros et al. [31], the study conducted by the author noted that walking performance is affected by path complexity and dual-task situations. Additionally, recent studies have demonstrated that performing multiple tasks or splitting attention between tasks can lead to a decline in walking performance, even among healthy individuals [32]. This is also observed in individuals who have neurological disorders [33,34]. Earlier research has demonstrated that when older individuals are tested under dual task conditions, they exhibit a decrease in their gait velocity, cadence, and stride time variability [35,36].

Deterioration in motor performance and speed during dual tasks was greater in females than in males, while males experienced a decline in cognitive ability when performing dual tasks compared to females. The study had certain limitations, including the psychological and physical condition of the patients throughout the research. Additionally, another limitation was the lack of documentation regarding the education levels and the absence of control for general cognitive ability and mobility task chosen, the speed measurement through the OneStep application has limitations. While it is easy to use and commonly employed in clinical settings, this method only offers a basic assessment of mobility speed. Conducting further evaluations of gait, which are more extensive and yield more detailed results (such as using inertial sensors), will offer more nuanced information. Second, we only assessed one secondary cognitive task. Different cognitive tasks may be differentially challenging across sexes. So authors recommend conducting a similar study with a larger and more diverse sample population that includes individuals with varying psychological and physical conditions. Additionally, the study could benefit from including measures to control for general cognitive ability and collecting more detailed information about participants’ education levels. Further study needed to be done to clarify the relationship between anatomical sex differences and gait speed test, while also distinguishing between cultural and physical factors that may contribute to ethnic differences. We utilized OneStep to perform speed analysis of the participants’ movements. To enhance these findings, future studies could incorporate three-dimensional motion analysis systems to examine the kinematics in greater detail. Additionally, our sample consisted solely of young, healthy Arab adults. It would be beneficial for future studies to include a more diverse range of older adults, as they are at a higher risk of falling and may exhibit different motor responses.

**CONFLICTS OF INTEREST**

No potential conflict of interest relevant to this article was reported.

**FUNDING INFORMATION**

None.
AUTHOR CONTRIBUTION


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REFERENCES

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Authorship assignment to AI is prohibited. ARM discourages the use of generative AI tools for the purpose of creating any types of content (including text, tables, and figures) for scientific manuscripts. If such tools are used, the authors must report their use transparently. In addition, authors who employ generative AI tools are solely responsible for all content produced and submitted. However, the use of AI tools to enhance the linguistic quality of a submission is considered acceptable and does not require specific disclosure.

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All submissions are made online at the journal’s online manuscript submission site (http://www.e-arm.org/submission) by the corresponding author. Submitted manuscripts are initially examined for format, and then appointed a submission number. For nonbiased peer review, authors’ names and institutional affiliations should not be mentioned in the text. The revised manuscript should be submitted through the same web system under the same identification numbers. The date of final review for the
1) ARTICLE PROCESSING CHARGES

*Annals of Rehabilitation Medicine* is an open access journal. To publish in *Annals of Rehabilitation Medicine*, authors are asked to pay an article processing charge (APC) on acceptance of their research paper. The APC for all published papers is as follows, plus VAT or local taxes where applicable. The currency KRW will be applied to the submissions from South Korea.

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- Image in this issue: 170 USD or 170,000 KRW
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†Note: As categorized by the World Bank, low-income countries will be eligible for a 20% discount on the updated APCs for original articles/brief reports/review articles/case reports. To find out if your country qualifies, please refer to the World Bank’s classification available at [https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html](https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html).

(This updated article processing charge is applied to all submissions as of Oct 1, 2023.)

6. PEER REVIEW PROCESS

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Conformity of the submitted manuscript to the submission instructions is examined upon submission. The Editorial Board may reject the manuscript or request the author to resubmit in the following cases: 1) Topic clearly out of scope / insufficient perceptual content 2) Work clearly does not meet sufficient standards of novelty or quality 3) Manuscript incomplete or incorrectly formatted 4) Suspected plagiarism in the manuscript.

2) PEER REVIEW PROCESS

Submitted manuscripts will be reviewed by two or more peer reviewers selected from the board’s database of expert reviewers. In addition, if deemed necessary, a review of statistics may be requested. Following review, the editorial board will decide whether the manuscript will be 1) accepted for publication, 2) subject to minor revision, 3) subject to major revision, or 4) rejected for publication. For manuscripts which are either subject to minor revision or subject to major revision, the corresponding author must resubmit the revised manuscript online. The revised manuscript should have the changes highlighted by using the Track Changes tool in Microsoft Office Word. In addition, the corresponding author must reply to both reviewers’ comments point by point, and explain in detail what changes were made in the manuscript. When considered necessary, the editorial board may make changes to the structure and phrases of the manuscript without compromising the integrity of the original paper. After completion of the peer review process, the editorial board will determine acceptance for publication and notify the corresponding author by e-mail. Manuscripts which do not comply with the present guidelines will be notified for correction or withheld from publication.

When a manuscript is not resubmitted within 2 months of notification, it will be considered that the authors have withdrawn the manuscript from submission. Manuscripts accepted for publication are generally published in order of submission, depending on the category of the manuscript and the date of acceptance for publication.

7. PREPARATION OF THE MANUSCRIPT

Use Microsoft Office Word (versions after 2003) and ensure correct spelling and grammar. Setup the MS Word document for 1-inch margins on letter or A4-sized paper. The manuscript must be written in 12-point font and the sentences must be double-spaced, including tables and figure legends. Each page should be numbered in the middle of the lower margin, and all sentences must be numbered sequentially throughout the entirety of the manuscript, starting with the title page. All papers must be accompanied by a title page. The title page should contain the title of the manuscript, a short running title, the authors’ names, academic degrees, respective affiliations, and ORCID. The corresponding author must be identified, and his or her contact information (postal address, e-mail, telephone and fax numbers) should be listed. The title should clearly describe the objective of the study and contain less than 20 words. The first letter of each word of the title should be in capital letters except for prepositions, articles, and conjunctions. Provide a short running title containing less than 10 words. The first letter of each word of the title should be in capital letters except for prepositions, articles, and conjunctions. Provide a short running title containing less than 10 words. In cases in which the authors belong to multiple affiliations, the affiliations during the study being reported should be matched to the authors’ names using a superscript of Arabic numerals. Conflicts of interest, funding information, author contribution and acknowledgements (when applicable) should also be located in the title page.
1) ORIGINAL ARTICLES

Original papers should be structured in the following order: Abstract, Introduction, Methods, Results, Discussion, Conflict of interests, Funding information, Author contribution, Acknowledgments (when applicable), References, Tables, Figure legends, and Figures. Maximum word count is limited to 5,000 words.

(1) Abstract

A structured abstract with the headings of Objective, Methods, Results, and Conclusion must succinctly describe the paper in 250 words or less. Use complete sentences and do not number the results. At the end of the abstract, list up to 5 relevant keywords which are in accordance to the Medical Subject Headings (MeSH) in the Index Medicus (http://www.nlm.nih.gov/mesh).

(2) Introduction

Clearly present the objective of the study and its relationship to earlier work in the field. A brief background to inform the readers of the relevance of the study may be necessary. However, avoid extensive review of the literature.

(3) Methods

Describe the participants or research materials of the study, and explain in detail the inclusion and exclusion criteria for both the experimental and control groups. Describe the experimental methods in a logical and systematic manner so that they can be reproducible by another investigator. Experimental drugs should be stated in the generic name. When proprietary brands are used, include the brand name and the name of the manufacturer in parentheses after the first mention of the generic name. When using experimental devices or other products, state the brand name then follow with the name of the manufacturer, in parentheses, e.g., Flow Cytometer (Coulter Electronic Inc.). To ensure anonymity during the peer review process, the authors’ affiliations or institutional setting of the study should not be revealed. Statistical analysis and criteria for determining significance should be described in enough detail to allow the knowledgeable reader with access to the original data to verify the reported results. An ethics statement should be placed here when the studies are performed using clinical samples or data, and animals.

Ensure correct use of the terms sex (when reporting biological factors) and gender (identity, psychosocial or cultural factors), and, unless inappropriate, report the sex and/or gender of study participants, the sex of animals or cells, and describe the methods used to determine sex and gender. If the study was done involving an exclusive population, for example in only one sex, authors should justify why, except in obvious cases (e.g., prostate cancer). Authors should define how they determined race or ethnicity and justify their relevance.

(4) Results

Summarize and describe logically the significant findings and trends observed in the results using text, figures and tables. Avoid extensive repetition of contents of the tables and figures in the text.

In statistical expression, mean and standard deviation should be described as mean ± SD, and mean and standard error as mean ± SE. In general, p-values larger than 0.01 should be reported to two decimal places, those between 0.01 and 0.001 to three decimal places; p-values smaller than 0.001 should be reported as p < 0.001.

(5) Discussion

Interpret the results in respect to the objective of the study, and describe differences with previous studies and significant findings which lead to the deduction of the conclusion. Refrain from excessive review of historic studies, textbook facts, or irrelevant references. Accentuate newly obtained observations from the study, and include significant limitations of the study.

(6) Conflicts of interest

Any potential conflicts of interest relevant to the manuscript should be described. If there are no conflicts of interest, authors should state that none exists.

(7) Funding information

All sources of funding applicable to the study should be stated here explicitly. All original articles, editorials, reviews, and new technology articles must state funding sources for the study.

(8) Author contribution

The individual contributions of the authors to the manuscript should be specified in this section.

(9) Acknowledgments

Persons who have made contributions to the study, but who are not eligible for authorship can be named in this section. Their contribution must be specified, such as data collection, financial support, statistical analysis, or experimentation. The corresponding author must inform the named contributor of the acknowledgment, and acquire consent before manuscript submission.

(10) References

- Cite only references which are quoted in the text. Limit the number of references 40.
- When quoting a reference in the text, refrain from stating the author’s name, and identify references with Arabic numerals in brackets such as [1], [2-4], and [5,7,9].
- The references should be listed in order of citation in the text.
- List all authors when there are 6 or fewer; when there are 7 or more, list the first 6, followed by “et al.”
- Journal names should be abbreviated according to the format listed in the Index Medicus. If the journal is not listed in the Index Medicus, refer to the list of title word abbreviations by the ISSN network (http://www.issn.org/2-22660-LTW A.php).

**Journals**


**Book & Chapter of book**


**Proceedings of academic conference**


**Thesis (Dissertation)**


**Tables**

Tables should be submitted separately from the text, and each table should be created in MS Word on separate pages, using double space throughout. They should be simple, self-explanatory, and not redundant with the text or the figures. Limit 5 tables per manuscript. The title of the tables should be written in phrases, and capitalized the first letter of the first word. The title should be placed above the table, and abbreviations and footnotes should be placed under the table. Number the tables in order of appearance in the text (e.g., Table 1, Table 2). All abbreviations used in the table must be spelled-out in full under the table in the following order: abbreviation, comma, full word (e.g., RM, rehabilitation medicine). Table footnotes should be indicated in superscripts in the following order: a), b), c)… but p-values should be indicated by asterisk (e.g., *p < 0.05, **p < 0.01, ***p < 0.001).

(12) Figure legends

Legends should be submitted separately from the text, and each legend should be typed on separate pages. They should be written in full sentences to describe the content of the figure, and only the first letter of the legend should be capitalized. For lengthy legends continuing beyond one line, the left margin of the following lines should start at the same point as the first line. Any symbols, marks or abbreviations made in the figure must be explained in the legend. Figures containing histologic slides should be accompanied by legends explaining tissue origin, stain method, and microscopic amplification.

(13) Figures

Figures should be uploaded online as separate files and numbered in order of appearance in the text (e.g., Fig. 1). When a single numbered figure contains 2 or more figures, the figure should be numbered with an alphabet letter following the number (e.g., Fig. 1A, Fig. 1B). Indicate focus points in the figures with markers such as arrows and arrowheads, etc. Image files must be of resolutions higher than 300 dpi, and less than 3 MB, in JPEG, GIF, TIFF, or Microsoft PowerPoint format. A single numbered figure containing more 2 or more figures such as Fig. 1A and Fig. 1B should be uploaded as a single file.

2) REVIEW ARTICLES

The abstract should contain no more than 250 words and 5 keywords. The text is structured in the order of Introduction, Main text, Conclusion, Conflict of interests, Funding information, Author contribution, Acknowledgments (when applicable), References, Tables, Figure legends, and Figures.

3) BRIEF REPORTS

General guidelines are the same as for the original article. The manuscript is structured in the order of Abstract, Main text, Conflict of interests, Funding information, Author contribution, Acknowledgments (when applicable), References, Tables, Figure legends, and Figures. A structured abstract is required and limited to 150 words, with no more than 3 keywords attached. Manuscripts
should be limited to 1,500 words of text including references and figure legends (not including abstract, tables, and figures), and no more than 10 references. The total number of figures and/or tables is limited to 3.

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General guidelines and order of manuscript preparation are the same as for the original article. Case reports are considered for publication only if they report rare conditions, atypical symptoms and signs, novel diagnostic or therapeutic approaches, or describe atypical findings for populations residing in Asia and the Pacific Rim. The editorial board will determine whether the case report fulfills the above criteria for acceptance of publication. The manuscript is structured in the order of Abstract, Introduction, Case report, Discussion, Conflict of interests, Funding information, Author contribution, Acknowledgments (when applicable), References, Tables, Figure legends, and Figures. The abstract should be nonstructured and limited to 150 words, with no more than 3 keywords attached. The introduction should briefly state the background and significance of the case. The actual case report should describe the clinical presentation and the diagnostic and therapeutic measures taken. The discussion should focus on the uniqueness of the case and should not contain extensive review of the disease or disorder. The combined number of tables and figures is limited to 5, and the number of references is limited to 10. Maximum word count is limited to 1,500 words including references and figure legends.

5) IMAGES IN THIS ISSUE
All images should be accompanied by a short description of the image and a brief and concise clinical review of the specific patient or clinical issue of no more than 500 words (excluding references) with references limited to 5. Image files must be of resolutions higher than 300 dpi for photographs, and 900 dpi for line art, waveforms, and graphs, in JPEG, GIF, TIFF, or Microsoft PowerPoint format. Images should make up a single figure, although they may contain more than one frame. The manuscript does not have an abstract.

6) LETTERS TO THE EDITOR
Letters should not have an abstract, tables, figures, and data supplements. Letters must be limited to roughly 500 words of text and no more than 5 references, 1 of which should be to the recent ARM article. Letters may have no more than 3 authors.

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For the specific study design, such as randomized control studies, studies of diagnostic accuracy, meta-analyses, observational studies, and non-randomized studies, it is recommended that the authors follow the reporting guidelines listed in the following table.

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All submitted manuscripts must be accompanied by the official Submission Application & Copyright Transfer Form of the Korean Academy of Rehabilitation Medicine. The Submission Application & Copyright Transfer Form must contain the title of the manuscript, date of submission, names of all authors, authors’ affiliations, and written signatures. Note the corresponding author and provide his/her affiliation, e-mail, telephone and fax numbers, and mailing address.

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1) FINAL VERSION UPLOAD
When accepted for publication, the authors’ institutional affiliations should be inserted into the text of the final revised manuscript and uploaded to the online submission system. Files containing figures should be of the highest resolution (at least 300 dpi for color figures, and 900 dpi for line art and graphs) should be also be uploaded in JPEG, GIF, or TIFF format, and must be named according to the figure number (e.g., Fig. 1.jpg).

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Galley proofs will be sent to the corresponding author for final corrections. Corrections should be kept to a minimum, must be returned within 2 days, otherwise publication may be delayed. Any fault found after the publication is the responsibility of the authors. We urge our contributors to proofread their accepted manuscripts very carefully. After the publication, if there are critical errors, they should be corrected as Corrigendum or Erratum.

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The editorial board retains the right to request minor stylistic and major alterations that might influence the scientific content of the paper. The final manuscript will be published following final approval by the editor-in-chief.
Checklist for Authors

General
☐ All elements of the manuscript are printed in English and double-spaced with 1-inch margins at top, bottom, and sides. Right margins are unjustified.
☐ All pages are numbered in the following order: title page, structured or standard abstract, body of the text, conflict of interests, Funding information, Author contribution, Acknowledgments (when applicable), references, legends, and tables.
☐ The text is consecutively line numbered.
☐ The Submission Application & Copyright Transfer Form is signed by the guarantor at original submission.

Abstract (applied to original articles, review articles, brief reports, and case reports)
☐ A structured abstract with the headings of Objective, Methods, Results, and Conclusion (A nonstructured abstract for case reports) must succinctly describe the paper.
☐ At the end of the abstract, relevant keywords are listed.

References
☐ All references have been checked for accuracy and completeness.
☐ Cite only references which are quoted in the text. Limit the number of references 40 for original articles, 10 for brief reports and case reports, and 5 for images in this issue and letters to the editor.
☐ Are numbered consecutively in the order they are cited in the text; all listed references have been cited in the text.
☐ Do NOT parenthesize the superscript numerals, and hyphenate (-) when citing 3 or more references in consecutive order.
☐ The format prescribed by the "Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals (ICMJE Recommendations)" has been followed. Examples provided under Instructions for Authors have been uploaded.
☐ List all authors when there are 6 or fewer; when there are 7 or more, list the first 6, followed by “et al.”
☐ Journal names should be abbreviated according to the format listed in the Index Medicus. If the journal is not listed in the Index Medicus, refer to the list of title word abbreviations by the ISSN network (http://www.issn.org/2-22660-LTWA.php).

Figure Legends
☐ Figure legends are provided for each figure.
☐ Figure legends are numbered and presented together in numeric order following reference page(s).

Tables
☐ Each table is headed by a title and numbered in Arabic numerals on a separate page.
☐ The title of the tables should be written in phrases, and capitalized the first letter of the first word.
☐ There are less than 5 tables in the text of original articles.
☐ Tables are cited in numeric sequence in the text.

Figures
☐ Each is numbered with an Arabic numeral and cited in numeric sequence in the text.
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A more complete description of each item that must be checked is provided under the appropriate heading in the Instructions for Authors.
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Every author took a certain role and made contribution to the study and the manuscript. In case of publication, I agree to transfer all copyright ownership of the manuscript to the Korean Academy of Rehabilitation Medicine to use, reproduce, or distribute the article.

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In signing this form:
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