



Original research

Decreased dynamic balance and dorsiflexion range of motion in young and middle-aged adults with chronic ankle instability



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ABSTRACT

Objectives: The purpose of this study was to compare dynamic balance and weight-bearing dorsiflexion range of motion between young and middle-aged adults with and without chronic ankle instability.

Design: Cross-sectional.

Methods: One hundred and two young adults were classified as either having chronic ankle instability (n = 38), copers (n = 27) or a healthy-control (n = 37). A total of 55 middle-aged adults were identified as having chronic ankle instability (n = 16), copers (n = 15) or a healthy-control (n = 24). Participants completed the weight-bearing lunge test and the anterior, posteromedial and posterolateral reach directions of the star excursion balance test.

Results: Middle-aged adults had shorter reach distances for each direction of the star excursion balance test compared to the young adults (p < 0.001). Regardless of age, participants with chronic ankle instability performed worse on the star excursion balance test compared to the copers (p < 0.05) and healthy-control group (p < 0.05). Similarly, participants with chronic ankle instability had less dorsiflexion compared to healthy-controls (p < 0.05), but not the copers group (p > 0.05).

Conclusions: Deficits in dynamic postural control do not continue to decline with advancing age in individuals with chronic ankle instability, however, these impairments appear to continue to persist compared to uninjured controls.

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Practical implications

Dynamic balance worsens with increasing age.

Individuals with chronic ankle instability have decreased dynamic postural control and dorsiflexion range of motion, regardless of their age.

Dynamic balance and dorsiflexion range of motion deficits observed in those with chronic ankle instability do not continue to worsen with increasing age.

1. Introduction

Most ankle sprains occur between 15 and 19 years of age.¹ While viewed as a short-term injury, at least 1 out of 3 individuals fail to fully recover.^{2,3} Chronic ankle instability (CAI) is the term used to

describe these lingering symptoms.⁴ It is thought that these persistent symptoms likely contribute to the decreased health-related quality of life and physical activity levels associated with this clinical pathology.^{4–6} In contrast, some people are able to return to physical activity without residual complaints after an ankle sprain and are commonly referred to as a copers.⁷ Therefore, the lingering symptoms and unintended consequences that are unique to CAI warrants further research towards understanding the long-term differences between those who do and do not have CAI.

There is a wide spectrum of both mechanical and sensorimotor impairments associated with the presence of CAI.⁸ One common sensorimotor impairment is decreased dynamic postural control when assessed using the Star Excursion Balance Test (SEBT).^{9–11} Whereas a common mechanical impairment observed is decreased dorsiflexion range of motion (DF-ROM) when measured using the weight-bearing lunge test (WBLT).^{11,12} Both of these impairments have been linked to declines in region-specific and global-health related quality of life.¹³ Therefore, deficits in these two clinical outcomes play a prominent role in understanding CAI.

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Recently published work indicates that CAI can lead to lifelong symptoms.^{14,15} A survey of an Australian community population aged 18 to 65 years found that a large proportion (49.7%) of respondents with chronic musculoskeletal ankle disorders described having symptoms that lasted longer than 10 years.¹⁴ This is further supported by an investigation finding middle-aged adults (aged 40 and older) with CAI displayed a lower global health-related quality of life relative to their healthy-counterparts.¹⁵ However, the current understanding regarding the impairments associated with CAI is primarily focused on adolescent and college-aged adults.^{16,17} This approach restricts our knowledge of whether insufficiencies observed in young adults with CAI persist as they get older.

Investigating insufficiencies that are present in middle-aged adults with CAI may lead to a better understanding of the consequences this clinical pathology has across the lifespan. As such, this may point clinicians and researchers to implementing more meaningful rehabilitation programs that could improve HRQoL for patients with CAI, regardless of their age. Therefore, the purpose of this study was to compare dynamic postural control and DF-ROM in young and middle-aged adults with CAI, copers, and healthy-controls. We hypothesized middle-aged participants would have decreased dynamic postural control and DF-ROM compared to the younger-aged adults and participants with CAI will have decreased dynamic postural control compared to the copers and healthy-control groups.

2. Methods

We conducted a case control laboratory study. The independent variables were injury (CAI, copers, and healthy-control) and age (young and middle-aged adults). The dependent variables consisted of the anterior, posteromedial and posterolateral reach directions of the SEBT and scores on the WBLT. The primary author was responsible for enrollment and data collection and therefore was not blinded to injury history or age classification.

A total of 157 participants were enrolled from a large regional university and the surrounding community. Based on previously published age ranges,¹⁵ participants were first classified as a young adult (age 18–40 years, $n = 102$) or middle-aged (age: 41–70 years, $n = 55$). Next, participants were further classified as a healthy-control ($n = 62$), copers ($n = 15$) or CAI ($n = 61$).

Inclusion criteria for those with CAI were based on recommendations set by the International Ankle Consortium (IAC).⁴ Participants with CAI were required to have: (1) an acute ankle sprain that resulted in swelling, pain and temporary loss of function for at least 1 day; (2) at least 2 repeated episodes of “giving way” in the past 6 months; and (3) perceived ankle joint instability determined by a score ≥ 5 on the Ankle Instability Instrument (AII) and ≤ 24 on the Cumberland Ankle Instability Tool (CAIT). All middle-aged adults with a history of an ankle sprain (CAI or copers) were required to have had their first acute ankle sprain before 40 years of age. In the event a participant reported having a history of bilateral ankle sprains, the limb with the greatest functional limitations according to the AII/CAIT and number of episodes of ‘giving way’ was used as the test limb. Participants allocated to the copers group were required to have: (1) an acute ankle sprain that resulted in swelling, pain and temporary loss of function for at least 1 day; (2) do not experience ‘giving way’; and (3) score < 5 on the AII and > 24 on the CAIT.⁷ Participants allocated to the control group were required to self-report no history of previous ankle sprain, no experiences of ‘giving way’, and a score of 0 on the AII and 30 on the CAIT.

All volunteers were excluded from participating if they: (1) had a lower extremity injury, low back pain or diagnosed with

a concussion within the 6 months prior to enrollment; (2) had ever been diagnosed with a balance, vestibular, neurological or respiratory disorder; (3) had a history of fracture or surgery in the lower extremity; and (4) currently using an assistive-walking device. All participants provided written informed consent and the study was approved by the university’s institutional review board.

Participants first completed a standardized healthy-history questionnaire consisting of questions focused on the number of previous ankle sprains, the most recent ankle sprain, number of episodes of ‘giving way’ in the previous six months and any previous self-reported injury at the back, hip/thigh, knee and lower leg/foot other than an ankle sprain. Additionally, participants were asked to quantify the number of years they perceived having symptoms related to CAI (e.g. instability and/or ‘giving way’). Next, participants completed paper versions of the AII and CAIT. After completing the questionnaires, participants performed the SEBT followed by the WBLT.

The anterior (SEBT-ANT), posteromedial (SEBT-PM) and posterolateral (SEBT-PL) reach directions of the SEBT were performed using previously established guidelines.⁹ Briefly, participants stood barefoot in the center of the star pattern with their hands placed on their waist. While maintaining a single-limb stance on the involved limb, participants were instructed to reach maximally in the designated reach direction with the non-stance limb by lightly touching the line and returning to the starting position. Each participant was given four practice trials for all three reach directions. The order of reach direction performance was randomized. Three trials were recorded for each reach direction and recorded in centimeters. The average reach distance was then normalized to the length of the participants’ stance limb. Leg length was measured as the distance from the anterior superior iliac spine to the most distal portion of the medial malleolus. The normalized average for each direction was used for statistical analysis. Lower normalized reach distance equates to decreased dynamic postural control. Test trials were discarded and repeated if the participant: (1) touched heavily or came to a rest at the point of touchdown; (2) participants hopped or took a step with the stance limb; and/or (3) lifted or shifted any part of the foot of the stance limb.

The WBLT was performed using the knee-to-wall principle.¹² Participants faced the wall and placed their involved foot on top of a standard metric tape that was secured to the floor and positioned perpendicular to the wall. Participants then performed a forward lunge until the anterior aspect of their involved knee touched the wall. Participants were gradually moved away from the wall in 1 cm increments until they could no longer touch the wall with the anterior aspect of their knee while keeping their heel firmly on the floor. Their foot was then adjusted in smaller increments forward until they could touch the wall with their knee without lifting the heel. Once this position was identified, the distance from the wall to the great toe was recorded in centimeters. Three test trials were performed, and the average was used for statistical analysis. Lower values represented decreased DF-ROM.

Separate 2×3 between-group analysis of variance models were conducted to explore the impact of Injury (CAI, copers, healthy-control) and Age (young adult and middle-aged adult) on demographic information, inclusion criteria and each dependent variable. A Tukey HSD post hoc analysis was used in the event of any significant main effect or interaction. Cohens d effect sizes along with 95% confidence intervals (CI) were calculated for each significant primary outcome measurement. Effect sizes were interpreted as weak ($d < 0.40$), moderate ($0.40 \leq d < 0.80$), and strong ($d \geq 0.80$). The *a priori* alpha level was set at $p < 0.05$. All statistical analyses were performed using IBM SPSS Statistics version 24.0 (IBM, Corp., Armonk, NY, USA).

Table 1
Group means and standard deviations for participant demographic information and injury characteristics.

	Younger-aged adults (Mean ± SD)			Middle-aged adults (Mean ± SD)			Main effect injury	Main effect age	Interaction
	CAI n = 38	Coper n = 27	Control n = 37	CAI n = 16	Coper n = 15	Control n = 24	p-value	p-value	p-value
Age	26.5 ± 6.8	24.8 ± 5.5	26.1 ± 5.5	51.4 ± 9.8	52.4 ± 9.0	56.1 ± 9.7	0.200	<0.001	0.238
Height (m)	1.68 ± 0.1	1.67 ± 0.8	1.69 ± 0.9	1.63 ± 0.1	1.69 ± 0.9	1.66 ± 0.1	0.500	0.220	0.378
Weight (kg)	75.7 ± 16.1	67.7 ± 13.5	70.2 ± 14.8	74.9 ± 17.3	77.4 ± 12.1	72.8 ± 13.3	0.452	0.133	0.256
BMI (kg/m ²)	26.6 ± 4.6	24.0 ± 4.2	23.8 ± 3.4	28.3 ± 7.7	27.2 ± 4.6	26.5 ± 5.5	0.060	0.003	0.763
# of LAS	2.9 ± 3.3	1.9 ± 1.6	0.0 ± 0.0	3.6 ± 3.5	2.5 ± 3.4	0.0 ± 0.0	<0.001 ^{a, b}	0.014	0.056
# of 'giving way' in past 6 months	4.2 ± 4.7	0.0 ± 0.0	0.0 ± 0.0	4.9 ± 6.9	0.0 ± 0.0	0.0 ± 0.0	<0.001 ^{a, c}	0.561	0.347
All	5.6 ± 1.6	2.4 ± 0.7	0.0 ± 0.0	6.3 ± 1.8	2.4 ± 1.1	0.0 ± 0.0	<0.001 ^{a, c}	0.197	0.181
CAIT	17.3 ± 4.9	26.3 ± 3.9	30.0 ± 0.0	15.6 ± 6.2	27.1 ± 4.7	30.0 ± 0.0	<0.001 ^{a, c}	0.774	0.237
First ankle sprain (years)	8.3 ± 6.9	10.6 ± 7.8	0.0 ± 0.0	25.6 ± 12.1	37.3 ± 42.5	0.0 ± 0.0	<0.001	<0.001 ^{d, g, h, i, j}	0.001
Most recent ankle sprain (years)	4.1 ± 5.7	6.1 ± 5.7	0.0 ± 0.0	11.9 ± 12.8	19.9 ± 12	0.0 ± 0.0	<0.001	<0.001 ^{d, f, h, i, j}	<0.001
Duration of symptoms (years)	6.7 ± 5.6	0.0 ± 0.0	0.0 ± 0.0	15.1 ± 11.9	0.0 ± 0.0	0.0 ± 0.0	<0.001	<0.001 ^{d, e, f, h, i}	0.002

Abbreviations: CAI = Chronic ankle instability; m = meters; kg = kilogram; BMI = Body Mass Index; All = Ankle instability index; CAIT = Cumberland ankle instability tool.

^e Within young adults: group difference between control and Coper.

^a Group difference between control and CAI.

^b Group difference between control and Coper.

^c Group difference between Coper and CAI.

^d Within young adults: group difference between control and CAI.

^e Within young adults: group difference between Coper and CAI.

^f Within middle adults: group difference between control and CAI.

^g Within middle adults: group difference between control and Coper.

^h Within young adults: group difference between Coper and CAI.

ⁱ Within CAI participants: group difference between young and middle adults.

^j Within Coper participants: group difference between young and middle adults.

Table 2
Star excursion balance test and weight-bearing lunge test; group means and standard deviations.

	Younger-aged adults (Mean ± SD)			Middle-aged adults (Mean ± SD)			Main effect injury		Main effect age		Interaction	
	CAI n = 38	Coper n = 27	Control n = 37	CAI n = 16	Coper n = 15	Control n = 24	F	p-value	F	p-value	F	p-value
SEBT-AN (%LL)	61.4 ± 6.6	64.9 ± 5.5	66.0 ± 4.7	58.8 ± 6.0	59.6 ± 5.7	62.4 ± 6.6	6.30	0.002	14.6	<0.001	0.53	0.238
SEBT-PM (%LL)	75.4 ± 11.3	84.7 ± 8.5	83.9 ± 10.7	68.7 ± 10.4	71.0 ± 12.0	70.5 ± 10.0	4.09	0.019	39.0	<0.001	1.60	0.378
SEBT-PL (%LL)	67.4 ± 16.2	79.0 ± 9.0	76.7 ± 10.1	60.5 ± 15.2	60.9 ± 16.5	60.1 ± 11.5	2.49	0.086	38.5	<0.001	2.39	0.256
WBLT (cm)	8.3 ± 3.6	9.4 ± 3.0	10.0 ± 3.8	6.9 ± 2.9	9.0 ± 3.3	9.3 ± 3.2	4.79	0.010	2.14	0.145	0.31	0.730

Abbreviations: CAI = Chronic ankle instability; SEBT = Star Excursion Balance Test; WBLT = Weight Bearing Lunge Test; ANT = Anterior; PM = Posteromedial; PL = Posterolateral; LL = Leg length; cm = centimeter.

3. Results

Group means and standard deviations for participant demographic information, inclusion criteria and additional injury characteristics are listed in Table 1.

No significant Injury by Age interaction or Injury main effect was observed for any demographic information ($p > 0.05$). There was a significant Age main effect indicating participants in the middle-age group were older ($p < 0.001$) and had a higher BMI ($p = 0.003$) than the young adults.

No significant Injury by Age interaction or Age main effect was observed for any inclusion criterion ($p > 0.05$). A significant main effect for Injury was observed for all inclusion criterion. Results from the post hoc comparisons can be found in Table 1. A significant interaction between Injury and Age was observed for the time since the first ankle sprain ($p = 0.001$), most recent ankle sprain ($p < 0.001$) and self-reported duration of CAI symptoms ($p = 0.002$). Results from the post hoc comparisons can be found in Table 1.

Group means and standard deviations for the WBLT and each direction of the SEBT are listed in Table 2.

No significant Injury by Age interaction ($p = 0.730$) or Age main effect ($p = 0.145$) was observed for the WBLT. There was a significant Injury main effect ($p = 0.010$) for the WBLT. Post hoc comparisons indicated that the CAI group had less DF-ROM compared to the healthy-control group ($p = 0.013$), which was associated with a moderate effect size ($d = 0.55$ [95% CI: 0.17, 0.92]). There was no sig-

nificant difference between the coper and CAI groups ($p = 0.146$) or between the coper and healthy-control groups ($p = 0.744$).

No significant Injury by Age interaction was observed for the SEBT-ANT ($p = 0.589$), SEBT-PM ($p = 0.204$) or the SEBT-PL ($p = 0.095$) reach directions. There was a significant Age main effect whereby the middle-aged adults reached less distance in the SEBT-ANT ($p < 0.001$, $d = 0.46$ [95% CI: 0.14, 0.78]), SEBT-PM ($p < 0.001$, $d = 0.98$ [95% CI: 0.64, 1.31]) and SEBT-PL ($p = 0.010$, $d = 0.96$ [0.62, 1.29]) directions compared to the younger-aged adults. There was a significant Injury main effect for the SEBT-ANT ($p = 0.002$) and SEBT-PM ($p = 0.010$) reach directions, but not for the SEBT-PL ($p = 0.086$) reach direction. Post hoc comparisons indicated that CAI participants had shorter reach distances in the SEBT-A direction compared to the healthy-control group ($p = 0.013$, $d = 0.65$ [95% CI: 0.27, 1.02]) but did not differ when compared to copers ($p = 0.146$). Participants with CAI also reached shorter distances in the SEBT-PM compared to the healthy-control group ($p = 0.024$, $d = 0.44$ [95% CI: 0.07, 0.81]) and coper group ($p = 0.010$, $d = 0.55$ [95% CI: 0.14, 0.96]). There was no significant difference between the coper and healthy-control group for either the SEBT-ANT ($p = 0.342$) or SEBT-PM ($p = 0.848$).

4. Discussion

A large number of studies investigating the mechanical and sensorimotor impairments associated with CAI have mainly focused

on adults under 40 years of age,¹⁶ limiting our understanding of any age by injury interactions associated with this clinical pathology. The aim of this investigation was to compare dynamic balance and closed-kinetic chain DF-ROM between young and middle-aged adults with and without CAI. We found participants with CAI had less DF-ROM and worse dynamic balance compared to the healthy-control group regardless of age. This provides new insights that suggest these deficits associated with CAI are not limited to young adults.

In this study we found middle-aged adults performed worse on all three directions of the SEBT relative to young adults. These shorter reach distances suggest middle-aged adults have worse dynamic balance than young adults. Similar findings have been shown on the anteromedial, posteromedial and medial reach directions of the SEBT between otherwise healthy young and middle-aged women.¹⁸ More recently, the 1000 Norms Project, an observational study aimed at collecting physical and self-reported outcomes in 1,000 healthy participants aged 3–101 years, found the posteromedial reach distance of the SEBT was negatively correlated with age.¹⁹ Balance relies on the interaction of multiple sensory and motor systems. Increasing age has been shown to result in a progressive decline the function of both of these systems and their interaction.^{20,21} This can make it difficult for an individual to adapt to changes within their environment and increase the likelihood of falling.²² Along with these neurophysiological changes, the fear of falling can also increase the risk of falling.^{23,24} The SEBT is a complex task that challenges an individual to move to the edge of their base of support without losing their balance. Therefore, some combination of these previously mentioned factors likely contributes to the decreased balance observed in the middle-aged participants.

The reduced SEBT reach excursion among participants with CAI found in the current study also supports previous research.⁹ With the inclusion of both young and middle-aged participants with CAI, our results provide novel information about the persistent effects of this clinical pathology. The reduced reach distances in participants with CAI may have been the result of a wide variety of mechanical and sensorimotor impairments that were not assessed in the current study. For example, Gabriner et al.²⁵ found the anterior reach is affected by mechanical restrictions and sensory deficits at the foot and ankle, whereas the posteromedial and posterolateral are impacted more by ankle strength and single-limb balance. Other investigators have also found reduced isometric hip external rotation and abduction peak torque to influence SEBT performance in young adults with CAI.²⁶ Collectively, these findings suggest that impairments throughout the lower extremity impact reach distances on the SEBT.

Our results also confirm previously reported deficits in DF-ROM between participants with CAI and un-injured controls.^{11,12} During closed-kinetic chain dorsiflexion the tibia slides anteriorly over the talus. Previous research using radiographic imaging has determined that individuals with CAI may present with an anteriorly translated talus.²⁷ A more anteriorly translated talus might create a bony block between the talus and tibia that could result in a loss of DF-ROM. This is further supported by research showing anterior-to-posterior talocrural joint mobilizations improve scores on the WBLT among those with CAI.²⁸ Therefore, we suspect that the deficits in DF-ROM observed among the participants with CAI might be explained by a positional fault of the talus. Given the positive outcomes associated with joint mobilizations, clinicians should continue using joint mobilizations when working with individuals who present with CAI. Additionally, researchers should continue examining the mechanisms behind joint mobilizations and the dosage needed to maintain improvements in DF-ROM.

We did not observe a significant age by time interaction for any primary outcome measure. This suggest that the impairments

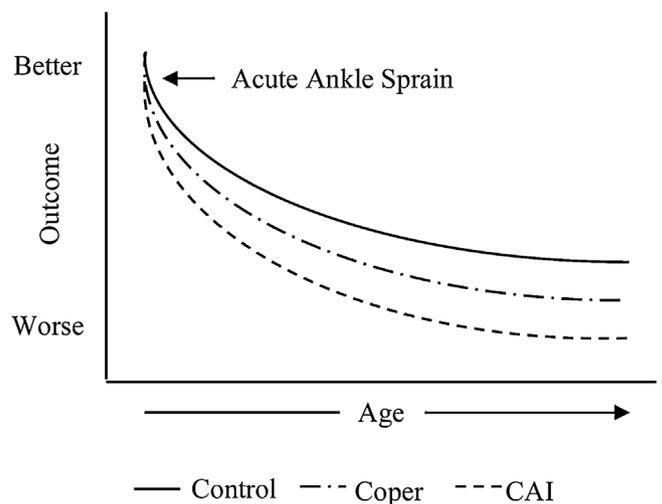


Fig. 1. Depiction of working model between CAI and age.

commonly observed in younger-aged adults with CAI remain consistent relative to their age-matched healthy counterpart and do not appear to worsen at a greater rate compared to their age-matched healthy counterpart (Fig. 1). Nevertheless, the lack of an age by injury interaction should not be overlooked. Prospective studies using different measures of dynamic balance and a modified version of the WBLT have found that worse performance on both these outcomes are independent predictors of falls among older-aged adults.^{29–31} Therefore, the persistent deficits observed within the CAI group in the present study may increase their risk of further long-term health concerns during the later stages of life (>70 years of age). This is underscored by recent work showing altered postural control variability in older-aged adults with a history of an ankle sprain compared to un-injured controls.³² Lastly, despite the inherent limitations associated with recalling the exact moment an injury may have occurred, the middle-aged participants classified as a Coper self-reported as being approximately 37 years removed from their ankle sprain. In comparison, the average time since the first ankle sprain in the middle-aged participants with CAI was only 25 years. A similar but less noticeable pattern was seen among the young-adults. Given this information, it would appear that something unique happens after an acute ankle sprain that isn't affected by time, but rather contributes to the development of CAI and the persistent impairments associated with it (e.g. dynamic balance or DF-ROM).

Finally, these findings build upon the current evidence documenting the impact of CAI beyond early adulthood. Simon and Docherty¹⁵ found middle-aged adults with CAI had lower scores on the physical component of the Short-Form 36 compared to their age-matched healthy counterpart. Previous researchers have determined that a variety of impairments contribute to the health-related quality of life reported by younger-aged (18–35 years of age) adults with CAI.¹³ Although we did not include any subjective outcome measures in the current investigation, it is possible that the observed deficits among our middle-aged participants might contribute to the lower health-related quality of life previously documented. Certainly, continued research is needed to better explore this relationship to confirm our speculation.

This study is not without limitations. Our overall aim was to determine the consequences of developing CAI as a young adult on dynamic balance and DF-ROM later in life. The recommended inclusion criteria by the IAC to identify participants with CAI is based on literature using exclusively young adults.⁴ Therefore, there is a clear need to develop and determine valid and reliable methods for assessing ankle instability in middle-aged adults. Moreover, we

further required the middle-aged adults with CAI in our study to have sustained an acute ankle sprain before the age of 40-years old. While the duration of symptoms reported by the middle-aged adults with CAI was higher comparable to the young adults, it is reasonable to speculate that some of the middle-aged participants with CAI may not have started to experience symptoms until they were older. This may have yielded significant differences in the amount of time individuals experienced functional limitations.

5. Conclusion

Participants with CAI had decreased dynamic balance and DF-ROM compared to the healthy-control group, irrespective of their age. This provides new insight towards the long-term impact associated with CAI and brings attention towards the need to educate patients on the importance of engaging in physical therapy to improve and maintain a healthy aging process.

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