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Original article

Evidence of a conservative gait strategy in athletes with a history of concussions

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Abstract

Background: A history of 3 or more concussions is frequently associated with numerous short- and long-term neuropathologies. Impairments in postural control are a known acute consequence of concussion; however, limited evidence exists on the effects of multiple concussions on gait. The purpose of this study was to assess gait stepping characteristics in collegiate aged student-athletes based on concussion history.
Methods: There were 63 participants divided into 3 even groups based on concussion history: ≥3 concussions, 1–2 concussions, and 0 concussion. All participants completed 10 trials of gait on a 4.9 m instrumented walkway. The dependent variables of interest included both gait stepping characteristics (step velocity, length, and width, double support time, and the percentage of the gait cycle in stance) and coefficient of variability (CoV) measures (step length, time, and width). The gait stepping characteristics were compared first with a MANOVA with follow-up 1-way ANOVAs and Tukey *post hoc* tests as appropriate. The CoV measures were compared with 1-way ANOVAs and Tukey *post hoc* tests.
Results: There were main effects for group for step velocity, length, width, and double support time. Overall, the 0 concussion group displayed typical healthy young gait parameters and performed significantly better than either concussion group. The 0 concussion group had a significantly greater step length CoV, but there were no differences in the step time or width CoV.
Conclusion: This finding provides evidence of subtle impairments in postural control during gait among individuals with prior history of concussion which could be an early indicator of future neurological deficiencies. The limited difference in the variability measures is consistent with prior static stance studies and could suggest the individuals constrain their motor systems to reduce variability. Taken together, these findings suggest a conservative gait strategy which is adopted by individuals with a history of concussions.

Keywords: Balance; Brain injury; Gait performance; Locomotion; Mild traumatic; Postural control; Postural stability; Variability

1. Introduction

A specific causative relationship between concussion history and later life neuropathology has not been definitively identified.[1] Long-term population-based studies have found inconsistent results; however, these studies are generally limited to small populations, chart reviews, or self-reported patient information. Among retired National Football League (NFL) players, there was a self-reported increased risk of clinically diagnosed depression and mild cognitive impairment in individuals with a lifetime history of 3 or more concussions.[2,3] NFL players also had a higher neurodegenerative related mortality rate than the general public.[4] Further, while the specific neuropathology and epidemiology remain debated, multiple case reports have identified the presence of chronic traumatic encephalopathy in deceased collision sport athletes.[5–7] In military settings, there was a positive relationship between increased number of mild traumatic brain injuries and increased risk of depression, post-traumatic stress disorder, and suicide risk; however, this may not be independent of other confounding variables.[8,9] Conversely, others have reported limited evidence of neurological impairment in either a population-based study or a patient-based neurological examination.[10–12]

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Similar to the later life issues, there have been inconsistent results when assessing short-term potential impairments in younger individuals with a history of multiple concussions. Multiple studies suggest that prior concussion history is associated with increased likelihood of future concussion, a worse initial post-concussion presentation, and prolonged recovery of recurrent concussion.[13–15] A history of concussions does not adversely affect performance on computerized neuropsychological testing in high school or collegiate aged individuals.[16–20] The effect of previous concussions on self-reported symptoms has been split with findings of both increased symptoms and no differences.[17,21] Prior concussion history has been associated with altered electrophysiological responses months to even years following the last concussion.[22–24] Finally, a history of at least 3 concussions has been associated with lower quality of life; specifically bodily pain, vitality, social functioning, and headache.[25]

Impairments in both static and dynamic postural control are a known acute consequence of concussion.[26,27] Standard clinical testing, utilizing non-instrumented static challenges, suggests recovery within 1 week of injury.[26,27] However, laboratory based investigations, assessing transitional and dynamic postural control, suggest these impairments may persist far longer.[28–33] Altered gait stepping kinematics have been identified to persist for up to 1 month following a concussion.[29,30,34–39] In individuals with a history of at least 1 concussion, both a conservative gait strategy, defined as reduced gait velocity and increased time in double support, and altered postural control dynamics have been identified.[40,41] The underlying pathophysiological mechanism for this strategy in individuals has not elucidated, but Martini et al.[40] speculated a strategy to reduce their time in less stable positions. This is consistent with acute and sub-acute concussive gait studies which have identified conservative gait strategies marked by reduced step and center of mass (COM) velocity, shorter steps, increased time in double support, and reduced separation of the center of pressure (COP) and COM which is suggestive of incomplete physiological recovery.[29,30,34–38,42–44]

There is no agreed upon number of concussions which result in neurological impairment; however, a history of at least 3 concussions appears to be frequently associated with numerous deficits.[2,3,22,25] Previous gait studies have either utilized acute post-concussion participants or non-athletes with a history of at least 1 concussion.[28–30,34–40,42–44] However, the relationship between concussion history and performance on gait tasks has received limited attention and could be an important marker of neurological consequences of concussion. Therefore, the purpose of this study was to assess gait stepping characteristics in student-athletes with differing concussion history; specifically, 1) 3 or more concussions (≥3), 2) 1 or 2 concussions (1–2), and 3) 0 concussion (0). We hypothesized the participants with a history of at least 3 concussions would present with impaired gait characteristics and exhibit a conservative gait strategy compared to the 0 concussion group and the 1–2 concussions group would fall along a range between the 0 and ≥3 groups.

2. Methods

2.1. Participants

Sixty-three National Collegiate Athletic Association (NCAA) Division I student-athletes were recruited at 2 separate universities by members of the research team for the study. The participants were divided into 3 groups based on their concussion history (≥3, 1–2, 0). The 0 concussion group was selected from a larger database of potential participants by tightly matching the gender, sport, and demographics of the ≥3 concussion group. The 1–2 concussions group was then matched upon the same criteria and there were no differences between groups for any demographic variable except concussion history (Table 1). Participants were excluded if they had prior or current orthopedic injury which would impair postural control, or any self-reported balance, psychiatric, visual, or vestibular deficits. All participants in the concussion groups were at least 3 months

Table 1
Participants' demographics (mean ± SD) and sports by group.

	≥3 concussions ($n = 21$)	1–2 concussions ($n = 21$)	0 concussion ($n = 21$)
Demographic			
Gender (male/female)	12/9	12/9	12/9
Age (year)	19.7 ± 1.3	18.9 ± 1.2	19.7 ± 1.3
Height (cm)	176.1 ± 14.9	176.9 ± 9.7	176.7 ± 12.1
Weight (kg)	84.1 ± 23.7	77.0 ± 15.5	83.7 ± 19.5
Concussion history (range)	3.7 ± 1.3 (3–8)	1.5 ± 0.5 (1–2)	0 ± 0
Sport			
Football	10	7	8
Women's soccer	3	3	3
Baseball	1	4	4
Cheerleading	2	1	1
Softball	2	0	2
Men's basketball	2	1	0
Rifle	0	0	2
Women's volleyball	0	2	0
Track and field	1	0	0
Swim and dive	0	1	0
Women's basketball	0	1	1
Women's tennis	0	1	0