Gait & Posture 62 (2018) 157–166

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Review article

Detecting gait abnormalities after concussion or mild traumatic brain injury: A systematic review of single-task, dual-task, and complex gait

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ARTICLE INFO

Keywords:
Brain injury
Locomotion
Balance

ABSTRACT

Background: While a growing number of studies have investigated the effects of concussion or mild traumatic brain injury (mTBI) on gait, many studies use different experimental paradigms and outcome measures. The path for translating experimental studies for objective clinical assessments of gait is unclear.
Research question: This review asked 2 questions: 1) is gait abnormal after concussion/mTBI, and 2) what gait paradigms (single-task, dual-task, complex gait) detect abnormalities after concussion.
Methods: Data sources included MEDLINE/PubMed, Scopus, Web of Science, and Cumulative Index to Nursing and Allied Health Literature (CINAHL) accessed on March 14, 2017. Original research articles reporting gait outcomes in people with concussion or mTBI were included. Studies of moderate, severe, or unspecified TBI, and studies without a comparator were excluded.
Results: After screening 233 articles, 38 studies were included and assigned to one or more sections based on the protocol and reported outcomes. Twenty-six articles reported single-task simple gait outcomes, 24 reported dual-task simple gait outcomes, 21 reported single-task complex gait outcomes, and 10 reported dual-task complex gait outcomes.
Significance: Overall, this review provides evidence for two conclusions: 1) gait is abnormal acutely after concussion/mTBI but generally resolves over time; and 2) the inconsistency of findings, small sample sizes, and small number of studies examining homogenous measures at the same time-period post-concussion highlight the need for replication across independent populations and investigators. Future research should concentrate on dual-task and complex gait tasks, as they showed promise for detecting abnormal locomotor function outside of the acute timeframe. Additionally, studies should provide detailed demographic and clinical characteristics to enable more refined comparisons across studies.

1. Introduction

National and international bodies have devoted significant attention towards the proper care, management, and rehabilitation of mild traumatic brain injuries (mTBIs), commonly called concussions, based on self-reported symptoms, neuropsychological testing, and standing balance performance [1–6]. Of these signs and symptoms, awareness of the significant impact of concussion on balance has increased over the past two decades, and standing balance assessment is an integral component of concussion management [3,7]. Yet, most daily activities demand ambulation. While the number of studies investigating various aspects of gait after concussion has grown over the past two decades, the research has not translated into clinical practice or recommended guidelines. Consensus guidelines use subjective visual assessments of gait; no standard objective gait assessment exists for concussion management [8]. Therefore, to guide future research and clinical implementation of objective gait assessments, we performed a complete review and synthesis of the literature regarding concussion and gait. Both concussion and mTBI, hereafter concussion, were included within the scope of this review as many studies have considered concussion

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https://doi.org/10.1016/j.gaitpost.2018.03.021
Received 4 September 2017; Received in revised form 1 March 2018; Accepted 7 March 2018

and mTBI synonymous [1,5].

Several challenges complicate the interpretation of studies examining gait abnormalities after concussion and may have contributed to the slow clinical translation. First, concussions are injuries that evolve over time [9,10]. Therefore, cross-sectional studies obtained at different timeframes may capture different physiological aspects of the injury. Second, daily ambulation includes a diverse set of activities. These include single-task simple gait, gait with simultaneous cognitive tasks (dual-task gait), and complex gait such as walking on uneven surfaces or in crowded environments requiring obstacle avoidance and navigation. Accordingly, researchers have examined a diverse set of gait tasks to examine if gait abnormalities are present in specific contexts after concussion. Further, the variety of experimental protocols employed across studies examine specific motor control impairments. For instance, single-task steady-state gait (i.e., single-task simple gait) along a straight path is largely controlled through subcortical locomotor processing with little executive control in healthy individuals [11]. However, dual-task gait utilizes frontal lobe executive functioning to facilitate the processing of simultaneous cognitive and motor demands [12]. Similarly, complex gait tasks involving obstacle avoidance, change of direction, or gait transitions involve locomotor adjustments that require simultaneous higher order cortical planning processing to plan and execute each movement [13–15]. A thorough understanding of how concussion affects, or does not affect, specific gait tasks may be an asset for researchers designing new studies to examine recovery after concussion and for clinicians hoping to have more sensitive tools in the assessment and management of concussion.

The purpose of this review was to direct future research by examining two questions: 1) is gait abnormal after concussion, and 2) what gait paradigms (single-task, dual-task, complex gait) detect abnormalities after concussion. To address these questions, this review was organized into four domains: single-task simple gait, dual-task simple gait, single-task complex gait, and dual-task complex gait based on the unique demands of each domain and how it may relate to motor control impairments post-concussion.

2. Methods

2.1. Search strategy

This systematic review of the literature followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach [16]. It was registered on PROSPERO (CRD 42017064118) and can be accessed in full at (https://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42017064118).

2.2. Search terms

The search terms related to concussion were “concussion” or “mTBI”. Search terms related to gait were “gait” or “walking”. Concussion and gait search terms were linked using AND. The entire search string was (concussion OR mTBI) AND (gait OR walking). Mesh terms related to mTBI included “brain injury”. There were no mesh terms related to gait or walking.

2.3. Search process

Two authors independently performed searches on March 14, 2017 on the following databases: PubMED/MEDLINE, Scopus, Web of Science, and CINAHL. The search was limited to articles published online or in print between January 1, 1950 and March 14, 2017. Search terms were identified in the title, abstract, and keywords. All results from the four databases were downloaded and examined for duplicates. Duplicate records were removed.

2.4. Inclusion and exclusion criteria

The inclusion and exclusion criteria followed the Population – Indicator – Comparator – Outcome (PICO) principle [17] to identify studies relevant to our research questions. Studies of all ages, genders, and human populations (e.g., athletes, military service members, civilians) were included. Non-human studies were excluded. Studies of concussion, sport-related concussion, or mild traumatic brain injury were included without restriction on the mechanism or setting of injury. Studies of unspecified brain injury or moderate, severe, or unspecified TBI were excluded. A control group or pre-concussion measurement was required as a comparator for inclusion. Case studies, case reports, and conference proceedings were excluded. All included studies had to report a gait outcome measure for inclusion. Each unique record was independently screened by two review team members to determine inclusion or exclusion. Disagreements were resolved through discussion and consultation with a third member of the review team.

2.5. Data extraction

Studies were divided into the following categories based on the protocols and outcomes of each study: single-task simple gait, dual-task simple gait, single-task complex gait, or dual-task complex gait. Studies were included in multiple categories if they examined multiple tasks relevant to different categories. The single-task simple category included all studies that reported outcomes from straight, steady-state gait without obstacles, uneven surfaces, cognitive tasks, or other instruction that may alter gait (e.g., foot placement for tandem gait). The dual-task simple category included all studies that reported outcomes from straight, simple gait with a simultaneous cognitive task or tasks. The single-task complex gait category included all studies that reported outcomes from non-simple gait without a cognitive task, including but not limited to tasks involving altered foot placement (e.g., tandem gait), non-straight gait (e.g., turning), obstacles or uneven surfaces (e.g., stair climbing, obstacle step-over, obstacle circumvention), and non-steady-state gait (e.g., gait initiation, gait termination). The dual-task complex gait category included all studies that reported outcomes from non-simple gait with a simultaneous cognitive task. The following data were extracted from each article included in this systematic review: title, authors, journal of publication, year of publication, sample size, subject characteristics, mechanism of injury, time since concussion, study design, experimental setting, experimental protocol, instrumentation, statistical analysis, and gait outcomes and results.

Gait outcome measures were divided into the following categories: gait speed; stride length and width; stride time and cadence, including double support time, stance time, and swing time; movement of the center-of-mass (CoM) in the mediolateral (ML) and anteroposterior (AP) planes, including range of motion, velocity, displacement, and acceleration; and other outcomes including variability between body segments, gait stability, and gait fluidity. Task specific outcomes were also included for complex gait tasks, such as obstacle clearance and movement of the center-of-pressure (CoP).

2.6. Quality assessment/risk of bias

The quality and risk of bias of each study was evaluated using a modified Downs and Black checklist for non-randomized studies [18]. Specifically, as no included study investigated the use of an intervention, questions 19, 23, and 24 were not scored. Additionally, as many of the included studies report experimental outcomes where the clinically important effect is unknown, question 27 was not scored. Notably, some questions that were retained still contained the term intervention. For these questions, the term “intervention” was substituted with “injury” to preserve the intent of the question. The maximum possible score for an article was 24 points. Each article was independently assessed by two reviewers, and discrepancies in scoring were resolved