Gait & Posture 62 (2018) 247–261

Contents lists available at ScienceDirect

Gait & Posture

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

Gait deviations in Duchenne muscular dystrophy—Part 1. A systematic review

Marije Goudriaan[a,b,*], Marleen Van den Hauwe[a,c], Joyce Dekeerle[a], Louise Verhelst[a], Guy Molenaers[b,d,e], Nathalie Goemans[c,d], Kaat Desloovere[a,b]

[a] KU Leuven – University of Leuven, Department of Rehabilitation Sciences, Leuven, Belgium
[b] University Hospitals Leuven, Clinical Motion Analysis Laboratory, Pellenberg, Belgium
[c] University Hospitals Leuven, Department of Child Neurology, Leuven, Belgium
[d] KU Leuven – Department of Development and Regeneration, University of Leuven, Leuven, Belgium
[e] University Hospitals Leuven, Department of Orthopedics, Pellenberg, Belgium

ARTICLE INFO

Keywords:
Duchenne muscular dystrophy
3D gait analysis
Gait deviations
Muscle weakness
Neuromuscular disease

ABSTRACT

Background: Although prolonged ambulation is considered important in children with Duchenne muscular dystrophy (DMD), articles describing gait deviations in DMD are scarce.
Research question: Therefore, our research questions were the following: 1) what are the most consistently reported spatiotemporal-, kinematic-, kinetic-, and muscle activity deviations in children with DMD in literature, 2) what is the quality of the studies describing these deviations, and 3) is there need for further research?
Methods: We conducted a systematic literature search for studies published before the end of June 2017 in six online databases. We created a data extraction form to define information on materials and methods and on the analyzed gait parameters for each paper included in the review. If enough information was available, we calculated standardized mean differences (SMDs).
Results: The search yielded nine articles, but generalizability was poor. Seventy-nine parameters were analyzed by seven research groups, but they only agreed on a decrease in walking speed (minimal SMD: 1.26), stride length (1.83), step length (1.80), dorsiflexion during swing (1.43), maximal power generation at the hip (0.92), maximal knee extension torque (0.99), maximal dorsiflexion torque (−1.30), and maximal power generation at the ankle (0.92), and an increased knee range of motion (−0.82) in DMD.
Significance: In order to keep children with DMD ambulant as long as possible, a clear understanding of their pathological gait pattern is necessary. However, gait deviations in DMD appear not well defined. Previous studies appear to be of an exploratory nature while using predefined gait parameters to assess an undirected null hypothesis. This made them prone to regional focus bias, thereby increasing the chance of a type I error. Therefore, further research is required to define the altered gait pattern in children with DMD.

1. Introduction

Duchenne muscular dystrophy (DMD) is the most common of muscular dystrophies affecting one in 3500–5000 boys that are born [1]. DMD is caused by a defective gene on the X-chromosome, which codes for the protein dystrophin. Dystrophin is expected to play an important role in "the stability of the muscle cell membrane in protecting the muscle fibers from contraction induced damage" [2]. When damage finally gets the overhand, muscles will predominantly consist of fibrofatty tissue [1]. So far, no cure has been found, and the affected children usually die in their third or fourth decade due to cardiac failure or pulmonary infections [1,3]. One of the treatment goals in children with DMD is to keep them ambulant as long as possible, aiming to preserve a clinically important function and to postpone spinal deformities and muscle contractures [1,4]. To achieve this goal, the altered gait pattern of children with DMD needs to be delineated and the potential underlying causes of their gait deviations need to be specified.

While 3D gait analysis to assess walking performance is part of the standard clinical care in children with neuromotor problems, such as cerebral palsy [5,6], this evaluation procedure is less often applied in children with DMD. In a clinical setting, walking ability in DMD is generally evaluated by means of the 6 min walk test [7], which is also used to assess treatment effect in clinical trials [8]. Although the 6 min walk test has been found to be a valid general measurement tool [7,8],

* Corresponding author at: KU Leuven – University of Leuven, Department of Rehabilitation Sciences, Leuven, Belgium.
E-mail address: marije.goudriaan@kuleuven.be (M. Goudriaan).

https://doi.org/10.1016/j.gaitpost.2018.03.020
Received 24 October 2017; Received in revised form 13 February 2018; Accepted 7 March 2018

it does not allow for a detailed analysis of joint kinematics, −kinetics, or muscle activity patterns of gait.

In 1981, Sutherland et al. were one of the first researchers using motion analysis to objectively quantify gait deviations in children with DMD [4]. They determined that three kinematic features could quantify disease progression: increased pelvic tilt, decreased dorsiflexion angle during swing and decreased cadence [4]. More recent studies used 3D motion analysis systems to study the gait pattern in children with DMD thereby calculating several spatiotemporal-, kinematic-, kinetic-, and/or muscle activity parameters [9–16]. However, their results are difficult to compare, due to differences in measurement methods, data analysis procedures and extracted parameter sets [9–15,17]. Hence, even though prolonged ambulation is considered important in children with DMD [1], their gait deviations appear not well-defined.

Therefore, the goals of part 1 of this research project were to create an overview of published studies that applied motion analysis to objectively quantify gait deviations in children with DMD, to provide a summary of the alterations in spatiotemporal-, kinematic-, kinetic- and muscle activity parameters reported in literature, and to assess the quality of the included studies. To meet this goal, we conducted a systematic literature search for studies published before the end of June 2017, based on exploration of six online databases.

2. Material and methods

2.1. Literature search

First, the PICO (Population, Intervention, Comparison and Outcome) tool was applied to assist with forming relevant keywords to conduct the systematic search [18]. Based on this PICO, the following medical subheadings (MeSH) were chosen: “muscular dystrophy, Duchenne” and “gait”. If usage of MeSH-terms was not allowed, the following keywords were used: “Duchenne” or “Duchenne’s”; combined with “dystrophy” or “muscular dystrophy” or “disease”. Also; only the abbreviation “DMD” was applied. As a replacement for the MeSH-term “gait”; we used the keywords: “gait”; “gait analysis” or “3D gait analysis”.

One reviewer (MG) checked four databases (Campell, Cochrane, Dare, and PubMed) to verify whether there were already previous published systematic reviews summarizing gait deviations in children with DMD. All systematic reviews published before June 2017, written in English, and using objective motion analysis techniques to study gait in children with DMD were included. We thereby defined ‘objective motion analysis techniques’, as measurement methods using 3D motion analysis systems from which spatiotemporal-, kinematic-, kinetic-, and/or muscle activity data could be derived. Titles and abstracts of the systematic reviews were checked by one reviewer (MG) to verify if they were relevant.

In the search for relevant articles, the same MeSH-terms and keywords were used as during the search for systematic reviews. Further, the following inclusion criteria were defined: 1) study population had to be aged between five and 18 years old, 2) a group of TD children needed to be used as controls, and 3) gait parameters needed to be objectively quantified. Studies only describing treatment outcomes, animal studies, or conference abstracts/-proceedings were excluded.

Then, three reviewers, two junior researchers (JD and LV) and one senior researcher (MG) systematically searched six electronic databases (PubMed, Web of Science, MedLine, Embase, Cochrane, and Google Scholar), to find articles objectively describing gait deviations in children with DMD. Titles and abstracts were screened by each reviewer individually (MG, JD, and LV). Eligibility of the full text papers was checked by four reviewers (MG, MVH, JD, and LV). In case of a difference in opinion between the reviewers (MG, MVH, JD, and LV) whether a study met the inclusion criteria, a consensus meeting was held with the option of consulting an additional senior researcher (KD). Finally, the reference lists of the included papers were also checked by one reviewer (MG). When a paper from the reference lists was considered eligible (based on title and abstract), the same procedure was followed as for the articles found in the online databases.

If studies were not available online or in the library of the KU Leuven, a request was sent to the authors. A maximal waiting period of six weeks after the last search was employed.

2.2. Data extraction

From the articles that were included in the review, information was extracted with the help of a custom-made data extraction form, based on the methods and results sections of the STROBE (Strengthening the Reporting of OBservational studies in Epidemiology) checklist for case-control studies [19,20]. Two reviewers (MG and MVH) filled in the data extraction form individually and compared their results. In case of differences between the two reviewers, the respective paper was checked. If the differences could not be solved, an additional reviewer (KD) was consulted to reach consensus.

Data extracted from each paper consisted of a description of the study populations, measurement systems, measurement procedures, applied statistics, and selected gait parameters. With respect to study population, we extracted sample size, including the rationale behind the sample size, such as indicating whether a power analysis was conducted prior to the data collection. Information on how the diagnosis of DMD was reached was also obtained. Additionally, the reviewers (MG and MVH) summarized age, anthropometrics, functional level (Vignos-scale), and steroid regiment for the children with DMD, since this information was considered to be important for the generalizability of the study results [12,21–23].

Specifications of the gait analysis procedure, including information on measurement devices, sample frequency, filter procedures, and marker protocols were also extracted. Especially different marker configurations could give different outcomes with respect to gait kinematics [24].

Concerning the gait analysis measurements, the same two reviewers summarized information about walking speed (self-selected or faster/slower) [25], as well as whether the children walked barefoot or with shoes (with or without orthoses), and the number of gait cycles that were included in the analyses.

We also considered it important to check how many parameters were analyzed, what type of statistics was applied, and which critical p-value was used in each study.

Then, spatiotemporal-, kinematic-, kinetic-, and muscle activity parameters, that were reported to be significantly different between DMD and TD, were summarized. For all parameters, we extracted the mean and standard deviation. When information about the mean and/or standard deviation was missing, we tried to estimate the required values via inspection of available figures and/or we used Eqs. (1) and (2) [26]. These formulas allow for conversion of the median (m) and the minimal (a) and maximal (b) values into mean (μ) values and standard deviations (σ) [26]. In Eq. (1), N is the sample size.

$$\mu = \frac{a + 2{*}m + b}{4} + \frac{a - 2{*}m + b}{4{*}N} \quad (1)$$

$$\sigma = \frac{b - a}{4} \quad (2)$$

For all parameters, outcome units were checked, since normalization to bodyweight (in case of kinetics) or leg length (or height) (in case of several spatiotemporal parameters) could have an influence on the outcomes [27]. If possible, the outcomes of the different studies were converted to the same units to allow for better comparison.

2.3. Data analysis

In case of sufficient information, we calculated the standardized