Clinical Gait Assessment in Relation to Benchmarking Robot Locomotion

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Abstract The objective of this paper is to identify clinical assessments that are potentially useful for benchmarking of bipedal locomotion. Results: Several clinical measures for static conditions and clinical measures for motion are suggested. Conclusions: Potentially useful clinical measures are identified. New metrics coming from new ambulant measurement techniques may be a good alternative for the qualitative clinical measures.

1 Introduction

In a recent paper on benchmarking bipedal locomotion, Torricelli et al. state that there is a growing awareness of the importance of benchmarking in the field of robotics [1]. The objective of the paper of Torricelli et al. was to define the basis of a benchmarking scheme for the assessment of bipedal locomotion that could be applied and shared across different research communities. For that purpose, a web-based survey was carried out first. Secondly, a common nomenclature was defined based on the work of Gentile [2] and Fleishman [3]. A common nomenclature is crucial, since the target

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group is multidisciplinary and different terms and definitions are often used by various disciplines working in the field of robotics. Subsequently, motor skills were classified, based on Fleishman, listing a subset of significant motor skills related to lower-limb motion and identifying related benchmarks.

However, most of these benchmarks describe the biomechanical property of the ability. This paper aims to identify clinical assessments useful for benchmarking of bipedal locomotion. Therefore, the proposed common nomenclature will first be compared to definitions used in clinical practice. Subsequently, potentially useful clinical assessments for benchmarking will be selected, based on their suitability for application in clinical practice.

1.1 Taxonomies Related to International Classification of Functioning

In the proposed scheme for benchmarking of bipedal locomotion, three terms were selected to define a common nomenclature (Fig. 1), based on the work of Magill [4]. These terms are: (a) Skill, defined as a task or activity with a specific goal (i.e. walking); (b) Ability, defined as the independent functional blocks needed to achieve a skill; (c) Performance, defined as the level of achievement of the goal.

In healthcare measures are generally defined according to the International Classification of Functioning (ICF) [5]. The ICF is a multipurpose classification designed to serve various disciplines and different sectors and to establish a common language for describing health and health-related states in order to improve communication between different users, such as healthcare workers, researchers, policymakers and the public, including people with disabilities.

In the ICF three components are defined (Fig. 2): (a) Body functions; these are the physiological functions of body systems (including psychological functions), (b) Activity; this is the execution of a task or action by an individual, (c) Participation; this is the involvement in a life situation. Furthermore the actual behavior of an individual is influenced by (a) Environmental factors, which make

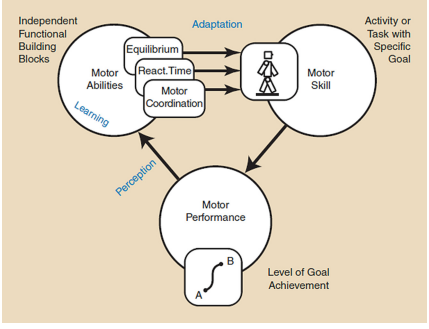

Fig. 1 The basic components of our benchmarking taxonomy: motor skills, motor abilities, and motor performance as suggested by Torricelli et al.

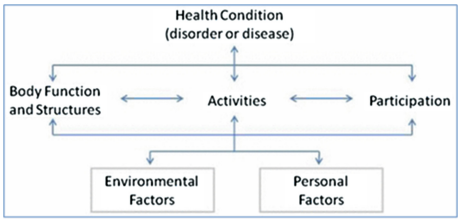

Fig. 2 Interactions and components of ICF

up the physical, social and attitudinal environment in which people live and conduct their lives, and (b) Personal factors, which are the particular background of an individual's life and living, and comprise features of the individual that are not part of a health condition or health states (i.e., habits, lifestyle).

Although the nomenclature and definitions differ between the two taxonomies they also seem to have a lot in common. For facilitating the discussion on benchmarking of bipedal locomotion, the taxonomy as proposed by Torricelli et al. is used in this paper.

1.2 Clinical Assessments for Bipedal Locomotion

In clinical practice, and especially in the field of rehabilitation medicine, clinical scales are used for decision making and/or evaluation of patients. These scales are used to describe the abilities (i.e., muscle force, sensation, etc.) and skills (i.e., walking, climbing stairs, etc.). Scales used in clinical practice should by reliable, reproducible and valid. A potential problem for benchmarking is that a lot of these scales are specific for a particular diagnosis, meaning that they are only validated for a specific patient group. A crucial prerequisite of clinical scales for benchmarking is that they are suitable for different patient groups (and healthy elderly). Another essential factor, which may be even more important, is the minimal important difference (MID). This MID is defined as the smallest change in a treatment outcome that a patient would identify as important. Last but not least, measurements should be validated in different languages.

In general, existing clinical measures don't distinguish between body posture or body transport (as is suggested in the paper of Torricelli). Measures either focus at static conditions (i.e., static balance), with or without (internal) perturbations, or at conditions where the body is in motion (i.e., walking, climbing stairs). Therefore, the current paper identifies clinical scales based on their corroboration with abovementioned factors concerning practical applicability, that can be used for benchmarking of motor skills related to lower-limb motion.

2 Method

Outcome measures were identified from a random selection of various databases, such as:

- http://www.meetinstrumentenzorg.nl/
- http://www.rehabmeasures.org/rehabweb/allmeasures.aspx?PageView=Shared
- http://geriatrictoolkit.missouri.edu/

3 Results

Suggested measures for static conditions: Berg Balance Scale (BBS), Timed Balance test (TBT), Reach test (RT). Suggested measures for motion: 10 m walk test (10 MWT), 6 min walk test (6 MWT), Functional Ambulation Category (FAC), Rivermead Mobility Index (RMI), Timed up and Go (TUG), L-Test (LT), Eight walk test (8 WT), Dynamic gait index (DGI), Functional Gait assessment (FGA), Stairs Test (ST), Falls efficacy Scale (FES).

4 Discussion

This paper describes the selection of potentially useful clinical measures for benchmarking of bipedal locomotion.

A possible disadvantage of these scales is that they are based on observation and that outcomes are often defined on a general level. New quantitative and reliable metrics might offer a solution for this problem. In the INTERACTION (training and monitoring of daily-life physical INTERACTION with the environment after stroke) project (EC FP7 Strep FP7-ICT-2011-7-287351), an unobtrusive and modular system for monitoring of daily life activities of stroke subjects and physical interactions of upper and lower extremity motor function with their environment was developed and validated. First results showed that the data measured by this system, which consists of inertial motion units (IMU's) and force sensors, correlate very nicely with clinical scales like the BBS, TUG and 10 MWT. Moreover, it provides additional quantitative information that is essential for discrimination between normal and abnormal (compensatory) movements while performing these tests [6].

Furthermore, measurements using this system can be conducted both in a controlled (movement lab) and uncontrolled (at home) environment [7].

5 Conclusion

Potentially useful clinical measures to benchmark bipedal locomotion were identified using the framework described by Torricelli et al. Important factors guiding the selection of clinical measures are generalizability over different patient groups, validity and reproducibility of the results, in combination with the minimal important difference. New metrics coming from new developments in the area of ambulant measurement techniques may be a good alternative for the existing clinical measures.

References

1. Torricelli, D., González-Vargas, J., Veneman, J.F., Mombaur, K., Tsagarakis, N., del-Ama, A. J., Gil-Agudo, A., Moreno, J.C., Pons, J.L.: Benchmarking bipedal locomotion. IEEE Robot. Autom. Mag. Sept. 2015. DOI:10.1109/MRA.2015.2448278
2. Gentile, M.: Skill acquisition: action, movement, and neuromotor processes. In: Carr, J.H., Shepherd, R.B., Gordon, J. (eds.) Movement science: foundations for physical therapy in rehabilitation, pp. 93–154. Aspen Publishers Inc., Rockville, MD (1987)
3. Fleishman, E.A., Quaintance, M.K.: Taxonomies of human performance. Academic Press, Orlando, FL (1984)
4. Magill, R.A.: Motor learning and control: concepts and applications. McGraw-Hill, New York (2007)
5. International Classification of Functioning, Disability And Health: ICF. WHO Library Cataloguing-in-Publication Data. © World Health Organization 2001. ISBN:92 4 154542 9. http://psychiatr.ru/download/1313?view=name=CF_18.pdf
6. van Meulen, F.B., Weenk, D., Buurke, J.H., van Beijnum, B.F., Veltink, P.H.: Ambulatory assessment of walking balance after stroke using instrumented shoes. J. NeuroEng. Rehabil. **13**, 48 (2016). DOI:10.1186/s12984-016-0146-5
7. van Meulen, F.B., Klaassen, B., Held, J., Reenalda, J., Buurke, J.H., van Beijnum, B.-J.F., Luft, A., Veltink, P.H.: Objective evaluation of the quality of movement in daily life after stroke. Front. Bioeng. Biotechnol. **3**, 210 (2016). doi:10.3389/fbioe.2015.00210