A COMPREHENSIVE APPROACH TO IMPROVE BALANCE AND REDUCE FALL RISK THROUGH INTEGRATION OF TREATMENT AND MONITORING TECHNOLOGIES

Solomonow-Avnon Deborah [1], Masculo Felipe [2], Ngo Chuong [3], Valenti Giulio [2], Batista Joao-Pedro [4], Ejupi Andreas [2], Halperin Uri [5], Zicherman Yehuda [5], Wolf Alon [1], Bollheimer Cornelius [4], Leonhardt Steffen [3], Heribert Baldus [2]

[1] **Biorobotics and Biomechanics Lab (BRML)**, Faculty of Mechanical Engineering, **Technion – Israel Institute of Technology**, Haifa, Israel, [2] **Philips Research**, Eindhoven, The Netherlands, [3] **Medical Information Technology**, Helmholz-Institute for Biomedical Engineering, RWTH, Aachen Germany, [4] **Geriatric Medicine – Med. Clinic VI**, Uniklinik RWTH, Aachen, Germany, [5] **Mopair Technologies**, Hadera, Israel

Introduction

Clinic-based rehabilitation and specific therapy programs may suffer from low patient compliance and relatively high cost. The rehabilitation success achieved is assessed during clinical visits rather than continuously and the assessments are often subjective.

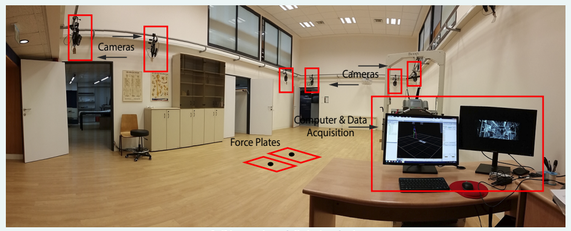
Seated exercise technology (SET) is a new approach to improve gait and balance in elderly or neurologically impaired populations at high risk for falls. SET integrates an exercise intervention with Balanseat (Mopair Technologies, Hadera, Israel) complemented by two wearable sensors - GoSafe (Philips Lifeline, Framingham MA, USA) and IPANEMA (MedIT RWTH Aachen, Aachen, Germany) to monitor and adapt treatment outcomes remotely, from the comfort of a nursing home or the patient's own home. Results from previous studies showed improvements ranging from 18% to 48% of standard physical function test scores after using Balanseat. GoSafe and IPANEMA's sensors were also able to improve the ability of physiotherapists in measuring walking and balance parameters. The implications of this integrated approach will potentially overcome the downfalls of clinic-based programs by:

- Monitoring progress continuously and objectively during daily life, via specialized sensor algorithms.
- Facilitating and accelerating treatment adaptation.
- Increasing patient compliance by reducing the burden of clinic-based programs on the patient, including elimination of appointment scheduling and travel.
- Reducing cost by reducing the surveillance need for a clinical facility and the presence of medical professionals during each clinic-based testing and treatment session.

The aim of this study were to measure and to validate walking and balance parameters measured by wearable sensors (GoSafe and IPANEMA) against a gold-standard motion analysis system.

Methods

During standard clinical tests, Timed "Up and Go" (TUG) and 10 Meter Walking Test (10MWT) at different speeds (i.e., slow, self-selected comfortable, fast), we extracted parameters of walking speed, stride time and cadence with GoSafe and IPANEMA sensors in 80 trials on 8 healthy adults and compared them to those from a Vicon three-dimensional motion analysis system (Oxford Metrics Ltd., Oxford, UK).
Each test was performed with and without a unilateral ankle weight used to simulate impaired gait.



3-Dimensional Gait Analysis

Results

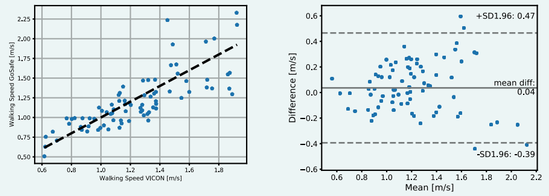
GoSafe

The GoSafe gait quality measurements were evaluated by performing a comparison against the reference values provided by the VICON system during the 10-meter walk tests. Since both GoSafe and VICON measure walking speed and stride time, these two measurements were compared directly via scatter plots and Bland-Altman plots. GoSafe's walking intensity was evaluated by comparing the average values provided in the trials with and without ankle weights at corresponding walking speeds.

All 10-meter walk trials for which it was possible to synchronize the GoSafe and VICON data were included in the analysis. This resulted in a total of 80 trials from 8 different study participants being included.

Walking speed

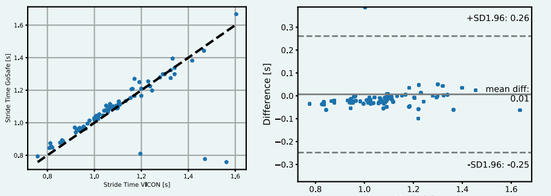
Walking speed measured by GoSafe showed strong correlation with the reference .



Comparison between walking speed measured by GoSafe and VICON. Scatter plot (left) and Bland-Altman plot (right). Pearson's r= 0.793 (p<0.001), Spearman's ρ = 0.842 (p<0.001)

Stride time

Stride time measured by GoSafe has strong correlation with the reference provided by VICON.



Comparison between average stride time measured by GoSafe and Vicon. Scatter plot (left) and Bland-Altman plot (right). Pearson's r= 0.696 (p<0.001), Spearman's ρ = 0.802 (p<0.001)

Walking intensity

A paired-samples t-test was conducted to compare the walking intensity values between the trials with and without ankle weight at different speeds. There was a significant difference in intensity values between the two conditions suggesting that this feature is sensitive to gait abnormalities.

Subject	Trial speed	Intensity natural	Intensity w/ ankle weight
000	fast	17.61125	7.653165
	normal	9.219171	7.21707
002	fast	13.15499	10.81275
003	fast	21.46495	9.62283
	normal	12.47659	8.613571
	slow	5.276828	6.904953
004	fast	16.05742	13.68391
	normal	11.28823	9.866118
	slow	8.104641	9.458779
005	fast	12.54033	9.302377
	normal	7.058419	7.101155
006	fast	19.39946	11.06853
	normal	8.931968	4.916044
007	fast	13.52159	8.356469
	normal	7.210637	4.228377
	slow	4.346322	1.361604
008	fast	10.82652	9.876982
	normal	6.702813	6.241169
	slow	5.11822	4.313081

Walking intensity measured by GoSafe with and without ankle weight. Paired-sample t-test: t(18)=3.828, p=0.001

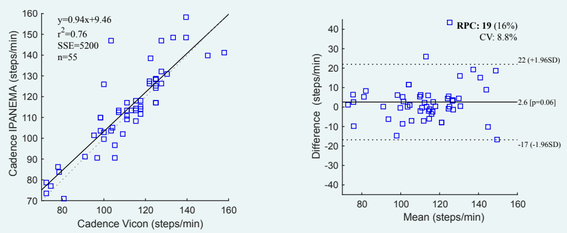
IPANEMA

We applied the peak detection algorithm on the pre-processed z-aligned acceleration data of the foot sensor and calculated the stride time by most frequent / median value over all strides.

IPANEMA data were evaluated by performing a comparison against the reference values provided by the VICON system during the 10MWT.

Cadence

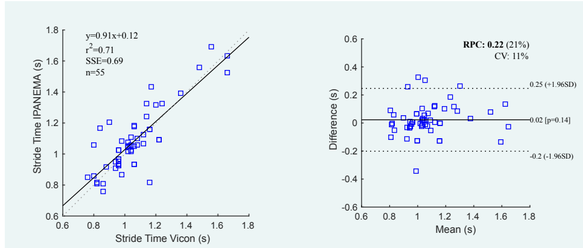
Cadence measured by IPANEMA has strong correlation with the reference provided by VICON, Pearson's r= 0.8431 (p<0.001), Spearman's ρ = 0.7302 (p<0.001).



Comparison between average cadence measured by IPANEMA and Vicon. Scatter plot (left) and Bland-Altman plot (right)

Stride time

Stride time measured by IPANEMA also showed strong correlation with the reference provided by VICON, Pearson's r= 0.8695 (p<0.001), Spearman's ρ = 0.8713 (p<0.001).



Comparison between average cadence measured by IPANEMA and Vicon. Scatter plot (left) and Bland-Altman plot (right)

Conclusions

The results of the evaluation show good agreement between both GoSafe's and IPANEMA's gait quality measurements confirming their feasibility as possible study outcome measurements when treated with the SET system.

For the GoSafe, the estimates of walking speed and stride time were strongly correlated with the reference values provided by the Vicon system while the stride regularity was shown to be correlated with the standard deviation of step times. Moreover, the walking intensity showed discriminatory power between natural gait and gait impaired by the use of ankle weights illustrating their sensitivity.

The IPANEMA's measurements also showed strong correlation with the reference values for cadence and stride time illustrating their ability to augment clinical assessments and provide a baseline for the GoSafe.

The next step is to build on these promising results and use the outcome measurements in a clinical trial as part of the SET system to improve/ monitor walking and balance.

www.setrehab.com

Visit SET - Seated Excercise Technology booth in the Neuro-Rehabilitation Congress

This activity has received funding from the European Institute of Innovation and Technology (EIT).
This body of the European Union receives support from the European Union's Horizon 2020 research and innovation program