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O29 - Humerus length estimation using a magneto-inertial sensor

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INTRODUCTION

In recent years, the use of inertial sensor technology in the field of human motion analysis has taken an increasingly important role. Despite the rapid technological advances, the reliability of kinematic quantities could be still critical for specific applications in the field of functional evaluation and rehabilitation. Within this context, the definition of personalized musculoskeletal kinematic models is crucial in order to describe the movement in a reproducible and accurate manner. A key step for the kinematic model calibration is the determination of bone segment lengths. The present study proposes a functional approach for the *in-vivo* estimation of the humerus length using a magneto-inertial measurement unit (MIMU). The accuracy of the method was evaluated based on the humerus length computed from the magnetic resonance imaging (MRI) as reference values.

METHODS

Five healthy subjects were involved in the study (3 males, 2 females, age: 35±5 years, body mass index: 21±2 kg/m^2). The MRI of each subject's right humerus was acquired. A MIMU, comprising three-axial accelerometers, gyroscopes and magnetometers (MTw2, Xsens), was attached on the subjects' wrist (Fig. 1a-b). Subjects executed the following calibration movement: five shoulder elevations in the sagittal plane keeping the elbow completely extended; five elbow flexion-extensions keeping the upper arm rigidly aligned to the trunk. Each subject repeated the previous functional movements three times. The humerus length was estimated as the distance D_{S-E} between the shoulder elevation axis and the elbow flexion-extension axis. The method estimates D_{S-E} as the difference between the minimum rotational radiuses of the MIMU during the two functional movements, $\mathbf{r}_s$ ed $\mathbf{r}_e$ in Fig.1a-b. The rotational radii were estimated according to a state-of-the-art functional method (Null Acceleration Point: NAP) [1], which is based on the rigid body kinematics equations using the accelerations, angular velocities and orientations gathered from the MIMU. For each subject, the error *e* between the estimated length D_{S-E} and the actual L_h, computed from the MRI as the distance between the center of the humeral head and the mid-point between the two distal epicondyles (Fig. 1c), was computed.

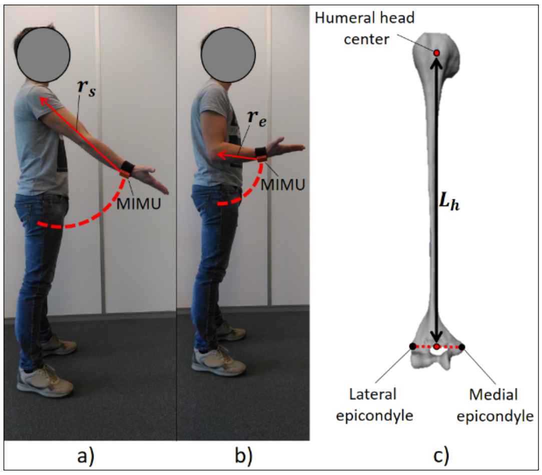

Figure 1. Experimental setup. a) Shoulder elevation in the sagittal plane; b) elbow flexion-extension;

RESULTS

The errors *e* for each subject were equal to: 4 mm, 9 mm, 22 mm, 16 mm e 1 mm. The mean absolute error and the standard deviation, over the 5 subjects, was 10±9 mm.

DISCUSSION

The findings of the study demonstrate that it is feasible to estimate *in-vivo* the humerus length using a functional method and a MIMU. The estimation errors could be related either to soft tissue artifacts and/or to improper execution of the functional movements (i.e. difficulty executing proper single-joint movements). The proposed methodology could be also applied to the estimate of other body segment lengths. In the field of kinematic model calibration, the proposed method represents a valid alternative to regressive methods based on anthropometric data (no subject-specificity) or to more time and cost consuming complex calibration systems [2]. The presented method has the advantage of being easy to use, fast and sufficiently accurate to estimate a bone length segment.

BIBLIOGRAFY

[1] M. Crabolu et al., BioMedical Engineering OnLine, 2017; 16(1): 34.
[2] Q. Yuan et al., IEEE ICRA, 2013; 6631335:5297-5302.

O30 - Comparative analysis of 12 methods using wearable inertial sensors for gait parameters estimation during walking

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INTRODUCTION

Inertial Measurement Units (IMUs) have been widely used to assess walking performance. Thanks to their small size, low cost and portability, in particular, they represent an ideal device for functional assessment outside the gait analysis laboratory. One of the main IMUs application is the identification of gait events (GE), used to quantify gait temporal parameters (GTP). GPT definition plays a relevant role in clinical, sport and home-monitoring applications [4]. In the literature, many GE estimation algorithms have been proposed, differing in modelling approach, number and positioning of IMU [1–7]. Previous analysis compared the performance of some of these algorithms [4] considering similar IMU positioning. The purpose of this study is to compare the performances of 12 methods proposed for GPT estimation, identified from a literature review, analyzing the influence of IMU positioning.

METHODS

Thirty-five healthy subjects (17F,18M;26.0±3.8y.o.;1.72±0.08m;69.0±13.1Kg) were recruited for this study. Five tri-axial IMUs (WaveTrack, Cometa, Milano, fc285Hz) were positioned on the feet, shanks and pelvis of each subject for acceleration and angular velocity acquisition. Four retroreflective markers were applied on each foot (toe, lateral malleolus, III and V metatarsal head) for 3D trajectories acquisition using stereophotogrammetry (BTS Smart-DX, fc250Hz). Participants were asked to walk for 2 minutes at their self-selected comfortable speed. GEs identified from stereophytogrammetric data were assumed as gold standard (GS) [8]. To identify the GEs from IMUs data 11 methods from the literature [1-7] and one newly proposed method (M1) were implemented. M1 is based on the local minima identification of the shank angular velocity. For each method, GPTs were calculated from GEs. Then, the following parameters were calculated: 1) the number of missed GEs relative to the number of true GEs (sensitivity) and of correctly detected GEs relative to the total amount of detected GEs (positive predicted values, PPV) [4] 2) the accuracy and the precision of GE estimation 3) the accuracy and the precision of GPT estimation.

RESULTS

The highest sensitivity and PPV were obtained for M1, [1] and [7] methods. Bland-Altman's plots show a higher accuracy and precision in GE detection for M1, [1] and [3] methods, and a higher accuracy and precision in GPT estimation for M1 and [1] methods.

DISCUSSION

The assessed performance of the 12 methods suggests that the most reliable results (low number of false positives/negatives, high accuracy and precision of GE and GPT estimation) are obtained for methods exploiting angular velocity signals from sensors mounted on the shank (M1, [1]). The comparison of these results to algorithm using shank linear acceleration ([7]) shows similar values for PPV and sensibility, while lower values of accuracy and precision are obtained. The positioning of the IMU on the foot ([3]) seems to provide as good accuracy and precision in GEs and GPTs detection as using sensors mounted on the shank (M1, [1]), but with an increased number of extra and missing events. In general, the worst performance in observed for methods exploiting the linear acceleration measured on the pelvis ([2,4]), both in terms of number of false positives/negatives, accuracy and precision of GEs and GPTs. These preliminary results, based on the functional assessment of healthy subjects, should be extended to subjects with specific gait abnormalities.

REFERENCES

[1] K.Aminian et al.,*J Biomech* 35(2002):689–99
[2] F.Buganè et al., *Comput Meth Prog Bio* 108(2012):129–37
[3] A. Ferrari et al., *IEEE Trans Neural Syst Rehabil Eng*, 24(2016):764–73
[4] D.Trojaniello et al.,*Gait Posture* 40(2014):487–92
[5] S.Khandelwal et al.,*SciTePress*(2014):197-204
[6] P. Catalfamo Formento et al., *Sensors* 14(2014): 5470-85
[7] J.Ah Lee et al., *J Med Syst* (2010) 34: 959–966
[8] C.M. O'Connor *Gait Posture* 25 (2007): 469–74

O31 - Instrumental evaluation of upper limb movements in subjects after cervical spinal cord injury

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INTRODUCTION

Cervical spinal cord injury (SCI) leads to extensive sensorimotor deficits affecting both somatic and vegetative functions below the injury level [1]. SCI subjects with cervical lesions at different levels (C5, C6 and C7) participated in this study. The main goal was to define and validate a protocol and a set of indicators for the functional evaluation of their movement strategies, in terms both of kinematic and muscle patterns. We verify if these parameters were able to characterize the different impairment levels and the changes due to spontaneous recovery in the acute stage or due to a rehabilitative treatment.

METHODS

Ten chronic-phase SCI subjects, two acute-phase SCI subjects (variable cervical lesion from C5 to C7) and four control subjects participated to this study. The functional evaluation protocol consisted of a clinical part based on muscle strength measures [2], and an instrumental part based on the acquisition of kinematic data and electromyographic signals during upper limbs tasks. The instrumental phase consisted of three exercises, chosen to evaluate the residual motor skills of a subject with cervical lesion: (i) 'reaching': subjects had to reach with their hand three targets positioned at a distance equal to their arm length and at their shoulder height, as wel as three targets positioned 30 cm higher than the previous ones; (ii) 'arc': subjects had to move their hand along an arc-shaped structure positioned in front of them, both in clockwise and counterclockwise direction, (iii) 'stabilization': subjects started the exercise with their arms resting on their legs and then moved both of them to a pre-defined position, maintained it for 5 seconds, and then returned to the starting position. The exercise was repeated for five different positions [3], presented in order of difficulty. A passive marker optoelectronic system (SMART DX, BTS Bioengineering, Milan, Italy) was used for the acquisition of kinematic data, and a wireless EMG system (EMG wave plus, Cometa, Milan, Italy) for recording muscle activity.

RESULTS

With this functional evaluation protocol, the analysis of cinematic data and electromyographic signals allowed us to identify the different motor strategies adopted by SCI subjects also as consequence to their cervical lesion. This protocol showed changes following a specific rehabilitation treatment that was added for one month to traditional treatments for five subjects. In addition, for the two acute subjects, the repetition of this protocol at 1, 3 and 6 months from the acute event allowed us also to quantify the improvement due to spontaneous recovery, coupled with the standard rehabilitation treatment both in terms of kinematic and muscular activation patterns.

DISCUSSION

This study provided a preliminary validation of a functional evaluation program easy to apply and well tolerated by subjects with spinal cord cervical lesions. This approach allowed an objective characterization of the strategies adopted during the execution of motor tasks. The prosed protocol and the selected indicators were not only able to identify the different muscular and postural compensation strategies adopted by each subject, but were also sensitive to variations in the motor abilities due to spontaneus recovery in the acute stage or to the effects of a specific rehabilitation treatment.

REFERENCES

[1] C. Long and E. Lawton, *Archives of Physical Medicine & Rehabilitation*, 1955: 249–255.

[2] H. Hislop, D. Avers, and M. Brown, Daniels and Worthingham's MuscleTesting: Techniques of Manual Examination and Performance Testing, 8 ed.: Saunders, 2007.

[3] G. van Lieshout, "User Manual Van Lieshout Test ", iRv:Hoensbroek2003.

O32 - Scapula dyskinesis in total and reverse shoulder arthroplasty: a quantitative pre- and post-operative prospective study

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INTRODUCTION

Recently, increasing attention has been paid to the analysis of shoulder kinematics in patients with Total Shoulder Arthroplasty (TSA) and Reverse Shoulder Arthroplasty (RSA). The clinical evaluation of changes between pre- and post-surgery was mostly accomplished through outcome scores, such as the Constant-Murley Score (CMS). Other biomechanical studies have focused on the alterations of scapula kinematics during arm elevation. To obtain an overall combined assessment, the aim of this study was to assess patients who underwent TSA and RSA, using the "Scapula Weighted CMS (SW-CMS)" [1]. We formulated two hypotheses: H_1, scapula kinematics is considerably altered in patients with TSA and RSA (SW-CMS scores significantly lower than CMS); H_2, at 6 months after surgery, shoulder joint recovery is completed, i.e. scapula compensatory movements are recovered.

METHODS

The study included 25 patients who underwent shoulder replacement: TSA (12 shoulders, age 62±7) or RSA (13 shoulders, age 76±8). Evaluations were performed: preoperative (T_0), and postoperative at 6 (T_1) and 12 months (T_2). At each evaluation, the CMS was completed and shoulder kinematics recorded for humerus flexion (FL) and abduction (AB). The kinematics was recorded with a stereophotogrammetric system (Vicon, UK). Anatomical coordinate systems were calculated with the U.L.E.M.A. software package [2], following ISB guidelines and joint rotation sequences of Kontaxis et al. [3]. Coordination plots were used to study the coordination between scapula rotations (PRotraction-REtraction, MEdio-LAteral rotation and Posterior-Anterior tilting) and humerus elevation. To calculate the "scapula weighting factor" of the SW-CMS score, coordination patterns (CP) were compared to reference bands (RBs), calculated on a group of 31 asymptomatic subjects (age > 60) [1]. A two-way repeated measure ANOVA was applied separately for TSA and RSA. Boxplots and paired two-sample t-tests were used to compare data distributions.

RESULTS

Kinematic analysis showed that: 1) all distributions were normal; 2) ANOVA was statistically significant ($p<0.05$) for all variables (Scores and Times), except for the interaction between Scores and Time in RSA. From the analysis of boxplots (Figure 1) and paired t-tests, we found a statistically different distribution of CMS and SW-CMS. RSA did not show significant changes between T_1 and T_2. TSA patients showed an improved humerus elevation both at T_1 and T_2, associated with an increased scapula compensatory movement at T_1 and then a lowering at T_2 (ME-LA is the most compensated rotation). RSA patients had a significant improvement in humerus elevation between T_0 and T_1. At T_2, there was a small improvement in AB. For these patients, at T_1 there was a general improvement of compensations and at T_2 there was an improvement for ME-LA and PR-RE, but a worsening for P-A.

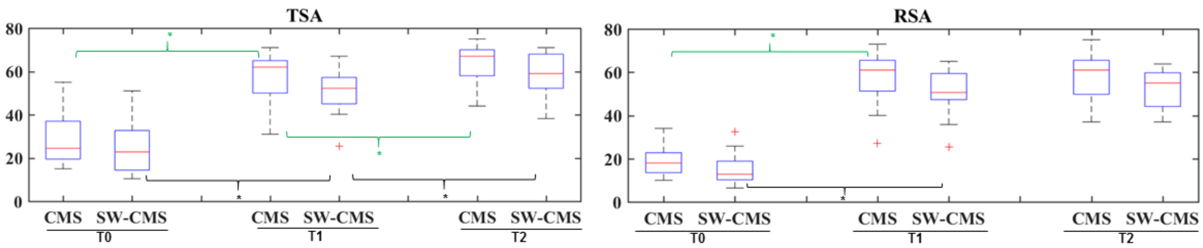

Figure 1 Boxplots of scores distributions at each Time

DISCUSSION

SW-CMS was significantly different from CMS. TSA and RSA present compensatory movement which are not resolved at 6 months and scapula dyskinesis is different between surgical treatments.

REFERENCES

[1] Cutti AG, et al. *J Electromyogr Kinesiol*. 2016 (**29**): 81-9
[2] Jaspers E, et al. *Gait Posture*. 2011 (**33**) :279-85
[3] Kontaxis A, et al. *Clin Biomech*. 2009 (**24**): 246-53

O33 - Wearable-sensor based pilot assessment of stair ascending in three neurological diseases

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INTRODUCTION

Stair negotiation is a common daily life activity frequently altered in elderly and subjects with neurological disorders [1,2]. Compared to level walking, stair negotiation is a significantly more biomechanically demanding task, highly associated to falls [1]. For these reasons, 43 clinical tests include an item on stair negotiation, which is assessed by ratings on an ordinal scale or through a stopwatch [2]. Although widely used, these scales provide little information about different aspects of the task. Aim of this study was the development and application of a method, based on a single inertial sensor (IMU), for the instrumented analysis of stair climbing in 3 groups of subjects with Multiple Sclerosis (MS), Parkinson's Disease (PD) and stroke (ST).

METHODS

30 subjects (age: 60±15 yrs) with neurological diseases (10 with MS, 10 with PD and 10 with ST) and 20 healthy subjects (HC, age: 58±14 yrs) were asked to climb 10 steps, as described in the mDGI clinical test (Item 8), wearing one IMU (Xsens, NL) positioned on the sternum with an elastic band. The following features were computed from accelerometric and angular signals: step frequency (peak frequency of the power spectrum of vertical acceleration), step symmetry and stride regularity (respectively, the first and second peak of the autocorrelation function of acceleration modulus [3]), gait smoothness (harmonic ratios of vertical (HR_V), medio-lateral (HR_{ML}) and antero-posterior (HR_{AP}) accelerations [4]), trunk AP and ML sway (standard deviation of trunk pitch and roll angles of the IMU). Between–group comparison was performed using ANOVA and Bonferroni-Holm post-hoc test.

RESULTS

No statistically significant difference among the 3 pathological groups was found in mDGI-Item 8 clinical score (MS: 5.0±1.7 pts; PD: 6.5±1.4 pts; ST: 6.0±1.8 pts). Instead, instrumental parameters (Table 1) showed a significant reduction of step frequency in all groups of patients compared to HC, while step symmetry, stride regularity and gait smoothness was reduced only in MS and ST subjects. Trunk AP sway was significantly increased in MS patients compared to all the other groups, while trunk ML sway showed a significant reduction in PD with respect to HC and people with MS.

Table 1. Mean (SD) parameters for HC *(a)*, MS *(b)*, PD *(c)* and ST*(d)* groups. Letters ^{a,b,c,d} indicate significant difference (p<0.05) with respect to the specific group (Bonferroni-Holm post-hoc test).

	HC *(a)*	MS *(b)*	PD *(c)*	ST *(d)*	$p_{(ANOVA)}$
Step Frequency [Hz]	2.0 (0.2) ^{b,c,d}	1.1 (0.4) ^{a,c}	1.6 (0.4) ^{a,b}	1.4 (0.4) ^{a}	<0.001
Step Symmetry [ ]	0.8 (0.1) ^{b,d}	0.3 (0.3) ^{a,c}	0.7 (0.1) ^{b}	0.5 (0.3) ^{a}	<0.001
Stride Regularity [ ]	0.8 (0.1) ^{b,d}	0.5 (0.2) ^{a,c}	0.7 (0.2) ^{b}	0.6 (0.2) ^{a}	<0.001
V smoothness - HR_V [ ]	3.3 (1.2) ^{b,d}	1.5 (0.6) ^{a,c}	3.0 (0.9) ^{b}	2.1 (0.9) ^{a}	<0.001
ML smoothness - HR_{ML} [ ]	3.1 (0.9) ^{b,c,d}	1.8 (0.7) ^{a}	2.2 (0.9) ^{a}	2.3 (0.7) ^{a}	<0.001
AP smoothness - HR_{AP} [ ]	2.9 (0.6) ^{b,d}	1.3 (0.4) ^{a,c}	2.4 (0.8) ^{b,d}	1.5 (0.8) ^{a,c}	<0.001
Trunk AP Sway [°]	1.3 (0.3) ^{b}	3.0 (1.4) ^{a,c,d}	1.3 (0.3) ^{b}	1.6 (0.5) ^{b}	<0.001
Trunk ML Sway [°]	4.3 (1.4) ^{c}	4.5 (1.4) ^{c}	2.7 (1.0) ^{a,b}	3.9 (1.4)	0.014

DISCUSSION

MS group showed the greatest alterations in stair climbing, as revealed by the worsening of all spatio-temporal aspects (step frequency, symmetry, regularity and smoothness) and by a significant increase of trunk AP sway, the latter suggesting a decreased axial stability. ST showed alterations in spatio-temporal aspects but not in trunk kinematics, while PD showed spatio-temporal parameters comparable to normative data, and a significant reduction of step frequency and trunk ML sway that can be ascribed to bradykinesia and rigidity. These preliminary results suggest that the proposed method is a quick and easy tool, which can discriminate healthy subjects from patients with different neurological disorders, and provide quantitative data about different components of stair climbing to complement clinical assessments. More subjects must be tested to confirm the present findings.

REFERENCES

[1] Jacobs JV. *Gait Posture* 2016;49:159-67. [2] van Iersel MB, et al. *Clin Rehabil* 2003;17(3):325-33. [3] Tura A, et al. *J Neuroeng Rehabil* 2010;7:4. [4] Menz HB, et al. *Gait Posture* 2003;18(1):35-46.

O34 - A new method for early detection of infants at risk of long-term neuromotor disabilities

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INTRODUCTION

The observation of spontaneous movements of newborns is predictive of neurological problems, which may lead to cerebral palsy and other developmental disabilities [1]. This is particularly important in the case of preterm newborns whose prematurity is responsible for complex changes in brain development, since it affects the processes of myelinogenesis, cortical development, neural migration and transynaptic degeneration. However, the method in current practice is totally based on human observation by highly trained technicians, whose number is quite limited. The alternative is an approach based on movement analysis instrumentation. Several experimental studies were carried out using 3D motion capture systems or wearable sensors (e.g. [2]), but remained confined to academia or clinical research institutions for their complexity. Here we evaluate the potential of a new markerless motion analysis system for studying movements of newborns in the hospital setting or at home.

METHODS

A commercial camera records the natural movements of newborn and a custom-built software 'MIMAS' - Markerless Infant Motion Analysis System [3] - automatically evaluates a set of quantitative indicators of the spontaneous motion patterns from binary images extracted from video sequences. The participants recruited for this study were chosen among the children born at the Gaslini Hospital and included two cohorts: (1) a population of preterm babies, born within the 32th gestational week and/or weighting less than 1.5 kg, in stable clinical conditions, in absence of pharmacological sedative treatment or respiratory support in the previous 4 weeks; (2) a population of healthy, full term babies. For each recruited child the following evaluations were carried out: (i) a MIMAS and a Magnetic resonance evaluation at the 40th gestional week (MRI provided information of high sensitivity for the diagnosis and the evaluation of the preterm babies allowing a deep investigation of the brain development and the eventual lesions associated with the deficits revealed by the clinical examination); (ii) a MIMAS evaluation at three months after birth; (iii) a clinical evaluation with BSID-III - Bayley Scales of Infant Development-III at 24 month after birth. We built a digital repository with a flexible and adaptable metadata model [4] to facilitate access and analysis of the collected data.

RESULTS

The database includes data of 120 preterm and 20 full-terms babies. We validated the stability and repeatability of the indicators provided by the motion system on a first subset of 30 babies. We found 27 stable indicators including the quantification of intensity and quantity of motion, symmetries between the motion of different body parts and parameters in the frequency domain. These indicators combined with a classification algorithm allowed us to discriminate movements of infants at different stages of maturation. Most importantly, in pre-term babies, the correlation of these indicators with evaluations based on brain imaging and with clinical outcomes provided a preliminary validation of the ability of the MIMAS system to detect possible neurological problems.

DISCUSSION

This work is a preliminary validation of a flexible, simple, stable and low cost system for early identification of infants at risk for motor disability, combined with a grid-enabled web platform for integrated digital biobanking in pediatric movement analysis, that provide an extended database with cognitive, behavioural and movement data. This system could lead to better understand and predict risks of disability and to target a selection of infants for early rehabilitative treatment, thereby reducing the risk of long-term disability.

REFERENCES

[1] Herskind, et al, *Dev Med Child Neurol*, 57(1), 29–36.
[2] Disselhorst-Klug, et al, *Experimental Brain Research*, 218(2), 305–313.
[3] Y. Osawa, et al, *IFMBE Proceedings*, Vol. 23), pp. 2043–2047.
[4] M.Izzo, A *BMC genomics* 15(3),1.