INTRODUCTION

Work-related shoulder injuries impact negatively the quality of life of workers and lead to problems of absenteeism and loss of productivity [1]. Despite prevention efforts, prevalence of these injuries is increasing [2]. Given the importance of this issue, workplace interventions must be improved. Studies have shown that multiple factors such as posture, force, amount of repeated movements and range of motion should be taken into account in the study of physical effort causing musculoskeletal injuries [3]. Wearable sensors such as inertial measurement units (IMUs) have been shown to be valid tools to assess shoulder movements during simple arm elevations as well as during complex lifting tasks [4]. The main challenge with commercial sensors is that they were developed for research or sports applications, but not necessarily for clinical rehabilitation purposes. As such, they provide neither appropriate interfaces nor adequate feedback for clinical applications.

OBJECTIVES

The long-term aim of this project is therefore to develop a low-cost wearable device using inertial measurement units (IMUs) able to analyze shoulder movement and provide feedback to clinicians and workers (both offline and in real time), to reduce the risk of musculoskeletal injuries. The specific objectives of this paper are 1) to develop an IMU data fusion algorithm to estimate the shoulder elevation and 2) validate the latter, when implemented on two different low-cost sensors (Actigraph GT9X and LSM9DS1), by comparing it to the elevation angle obtained with the data fusion algorithm of a validated commercial sensor system (Xsens MVN).

METHODS

DATA FUSION ALGORITHM

Inputs: the IMU 3-axis accelerations and angular velocities
Output: Arm elevation

Arm orientation can be described by three angles: plane of elevation, segment elevation and internal/external rotation. In this paper, we are mainly interested by segment elevation as it is the principal indicator related to the development of musculoskeletal disorders.

VALIDATION

10 tasks:
1) Shoulder flexion at 1Hz
2) Shoulder external rotation at 90° elbow flexion (1 Hz)
3) Shoulder flexion at 3Hz
4) Shoulder abduction at 3Hz
5) Shoulder external rotation at 90° abduction (1 Hz)
6) Shoulder abduction at 3 Hz
7) Trunk flexion with static arm elevation
8-9) Five “Z” movements on the frame of a mirror (clockwise and counter clockwise) 10) nine ball throws at 90° shoulder abduction (target distance of 2.85 m).

RESULTS

Correlation coefficient (r), root-mean-square error (RMSE) and average absolute error of estimate for both LSM and GT9X sensors

Comparison of the arm elevation obtained with the proposed data fusion algorithm (with LSM9DS1 and GT9X) to the arm elevation obtained with a Xsens MVN system

DISCUSSION AND CONCLUSION

The results show a high correlation (r > 0.90) for all tasks and a mean RMSE below 4.6° (1.66-11.24°) for the LSM sensor. The proposed data fusion algorithm is thus valid to estimate arm elevation. This algorithm yields better results for slower tasks (1,2,4,5,7,8,9) with a mean RMSE of 2.72° for (LSM) than for faster movements (tasks 3,6,10) with a mean RMSE of 8.9° for the LSM). The results obtained with the LSM9DS1 were better than Actigraph GT9X. While the same data fusion algorithm was used with both sensors, the higher sampling rate of LSM9DS1 (500Hz vs 100Hz) could explain these results.

The long-term objective of this work is to develop a low-cost wearable device using IMUs to analyze shoulder movements and provide feedback to clinicians and workers to reduce the risk of musculoskeletal injuries. Future work will consist in validating the system in a workplace environment, to miniaturize the system and to provide a meaningful data report to clinicians using the arm elevation data obtained throughout a day.

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REFERENCES