PHYSICAL ERGONOMICS OF TABLET INTERACTION WHILE SITTING

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INTRODUCTION

We present physical ergonomics assessment of typical tablet device usage. Tablet devices are becoming widespread and often even displace personal computers and laptops. However, while physical ergonomics of PCs and laptops was extensively studied in the past, there is only little knowledge of ergonomics of tablet devices. In particular the user assessment is complex due to portability of tablets, which allows a variety of tablet locations, orientations and holds which can be adopted by users. The purpose of this work was to identify typical postures, set of recruited muscles and health risks related to the tablet interaction.

Few previous works [1, 2] have measured head and neck posture, or wrist and shoulder posture of tablet usage, however they used predefined set of tablet hold configurations. They extracted joint angles directly from locations of markers attached to anatomical landmarks, which ignores such sources of error as marker drift during movement, joint displacement, or absence of skeletal anatomy. In contrast to this in our work we do not assume a particular posture for interaction and ask participants to take a pose and hold the tablet as comfortable for them. We record motion of the whole human body and analyze biomechanical indices simulated using an anatomically-correct musculoskeletal model.

METHODS

For the analyses we have used the dataset created by Bachynskyi et al. [3]. The data comes from 40 participants (26 males and 14 females) recruited on the local university campus. Mean age is 24.9, height 171.4 cm, and weight 67.4kg. The participants were asked to perform a repetitive target selection task on an iPad-sized and shaped surface. Targets were of 12 types depending on the size and approach angle, and participants performed 50 target selections in each condition. During the tasks the participants used sitting postures which they have considered comfortable, without constraints from the experimenter. 12 cameras of PhaseSpace Impolse motion capture system have tracked 38 active markers attached to all body segments of a participant at 480 Hz. To record main external forces acting on a user, the chair and platform under the feet were equipped with 8 force sensors collecting data at 125 Hz.

The data was pre-processed by custom Matlab scripts. Biomechanical simulation was performed in an open source software OpenSim [4] with a commercial musculoskeletal model of the Full-Body[1]. The outputs generated by Inverse Kinematics, Inverse Dynamics and Static Optimization are further consolidated into the single dataset. This allows fast and simple analysis of frame-level and aggregated data. The dataset contains posture and moment values for 109 joints, forces and activations for 236 muscles covering the whole human body.

We use Matlab and an interactive visualization tool [5] to perform analyses on the data. We compute average postures of each joint and compare it to movement ranges and neutral postures. Postures close to extreme are considered as health risk after prolonged use. Further, we consider average and peak joint moments. High values of average joint moments pose health risk after prolonged use; high peak moments can lead to an injury even in short interaction. We consider peak muscle forces, as a factor that can lead to a muscle or tendon injury. High average muscle forces lead to muscle stress and fatigue. In our analyses we focus on the body segments the most affected by the tablet usage: upper back and neck, shoulder and arm supporting the tablet, and shoulder and arm interacting on the

[1] http://www.musculographics.com

device. The most extreme value at each segment defines health risk for the whole segment.

RESULTS AND DISCUSSION

The results show that the typical posture selected for interaction with a tablet is incorrect and has high risk for users' health. In particular, the posture of upper back and neck is stressful and impose serious risk: average neck flexion differs by 42.6° from the neutral pose. Average and peak joint moments are also high for the neck which can lead to both RSI after prolonged use, or to an acute injury in neck joint. Average muscle forces are moderate which means that muscles are not actively recruited to support head and will not suffer from fatigue, however the peak muscle force is high, and can lead to injuries in neck extensor muscles.

Average elevation angle of the supporting shoulder is slightly larger than neutral zone, so the joint angle is not extreme, but muscles can fatigue after relatively short period. Average joint moment at shoulder is high which can lead to RSI after prolonged use, however peak joint moment is moderate, as result an acute injury is less probable. Average muscle force is high, as a result muscles will fatigue relatively fast. Peak muscle force is also high which can lead to a muscle strain. The elbow joint is in the neutral zone. Average joint moment is low and peak moment is also low. Average muscle force and peak muscle force are high for some muscles, however, there are redundant muscles with similar action which can be recruited if necessary, for example biceps can generate force if brachialis is fatigued. There is no such reserve for shoulder muscles to recruit in the case of fatigue.

Average shoulder elevation of the interacting arm is in the neutral zone. Average and peak joint moments are moderate, average moment is 35% lower than the moment of the supporting shoulder. Average muscle forces and peak muscle forces are only slightly lower than in the supporting shoulder, however the set of recruited muscles is different and there is more variability in recruitment. As a result the muscles of the interacting shoulder can be fatigued, but much slower than in the supporting shoulder. Average elbow flexion is 110.4°, which is at the border of neutral zone. Average and peak joint moments are moderate. Average muscle forces are low, but peak muscle forces are still high for some muscles. There is more variability in muscle groups of the interacting arm. This adds to more balanced usage of the musculature without exhaustion of a particular muscle.

The largest risks of tablet interaction in the typical postures are related with bad neck posture and fatigue of the supporting shoulder muscles.

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Table 1: Biomechanical indices for tablet interaction.

Body part	**Biomechanical indices**					
	Av. j. angle	**Av. j. moment**	**Peak j. moment**	**Peak m. force**	**Av. m. force**	**Stress level**
Neck	-31.5°	2.9 N·m	411.9 N·m	260.4 N	20.2 N	High
Supporting Shoulder	38°	2.3N·m	184.8 N·m	2588.8 N	83 N	Moderate
Supporting Arm	59.8°	1.2 N·m	46.1 N·m	2006.9 N	73.8 N	Low
Interacting Shoulder	19.2°	1.5 N·m	208.8 N·m	2351.7 N	77.5 N	Low
Interacting Arm	110.4°	1.8 N·m	137 N·m	2010.2 N	53.2 N	Low