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Manual Wheelchair Propulsion Efficiency on Different Slopes

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Abstract : In this study, an integrated sensing and modeling system for manual wheelchair propulsion measurement and propulsion efficiency calculation was used to indicate the level of overuse. Seven subjects participated in the measurement. On the level surface, the propulsion efficiencies were not different significantly as the riding speed increased. By contrast, the propulsion efficiencies on the 15-degree incline were restricted to around 0.5. The results are supported by previously reported wheeling resistance and propulsion torque relationships implying margin of the overuse. Upper limb musculoskeletal injuries and syndromes in manual wheelchair riders are common, chronic, and may be caused at different levels by the overuse i.e. repetitive riding on steep incline. The qualitative analysis such as the mechanical effectiveness on manual wheeling to establish the relationship between the riding difficulties, mechanical efforts and propulsion outputs is scarce, possibly due to the challenge of simultaneous measurement of those factors in conventional manual wheelchairs and everyday environments. In this study, the integrated sensing and modeling system were used to measure manual wheelchair propulsion efficiency in conventional manual wheelchairs and everyday environments. The sensing unit is comprised of the contact pressure and inertia sensors which are portable and universal. Four healthy male and three healthy female subjects participated in the measurement on level and 15-degree incline surface. Subjects were asked to perform manual wheelchair ridings with three different self-selected speeds on level surface and only preferred speed on the 15-degree incline. Five trials were performed in each condition. The kinematic data of the subject’s dominant hand and a spoke and the trunk of the wheelchair were collected through the inertia sensors. The compression force applied from the thumb of the dominant hand to the push rim was collected through the contact pressure sensors. The signals from all sensors were recorded synchronously. The subject-selected speeds for slow, preferred and fast riding on level surface and subject-preferred speed on 15-degree incline were recorded. The propulsion efficiency as a ratio between the pushing force in tangential direction to the push rim and the net force as a result of the three-dimensional riding motion were derived by inverse dynamic problem solving in the modeling unit. The intra-subject variability of the riding speed was not different significantly as the self-selected speed increased on the level surface. Since the riding speed on the 15-degree incline was difficult to regulate, the intra-subject variability was not applied. On the level surface, the propulsion efficiencies were not different significantly as the riding speed increased. However, the propulsion efficiencies on the 15-degree incline were restricted to around 0.5 for all subjects on their preferred speed. The results are supported by the previously reported relationship between the wheeling resistance and propulsion torque in which the wheelchair axle torque increased but the muscle activities were not increased when the resistance is high. This implies the margin of dynamic efforts on the relatively high resistance being similar to the margin of the overuse indicated by the restricted propulsion efficiency on the 15-degree incline.

Keywords : contact pressure sensor, inertia sensor, integrating sensing and modeling system, manual wheelchair propulsion efficiency, manual wheelchair propulsion measurement, tangential force, resultant force, three-dimensional riding motion
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