Representation of the Elderly Population with Active Human Body Models

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I. INTRODUCTION

Driving requires active movements of the head as well as the upper and lower limbs as a response to spatial and temporal information received from the environment. This motor control ability is fundamental in road traffic emergency scenarios, such as steering, braking and lane changing, in which a quick reaction to the impending danger is required. However, studies have shown that the motor performance slows down with increasing age [1], potentially diminishing the ability of elderly drivers to react to dangerous traffic scenarios. This slowdown is quantified through the measurement of the Reaction time (RT), defined as the time interval between stimulus activation and the response initiation, which plays a crucial role in quantification of the slowing motor performance in elderly people while driving [2]. Many studies found that the elderly subjects were not able to activate their muscles as quickly as their younger counterparts when trying to initiate movements, thus causing delayed RT [2]. Several biological factors, such as slower rate of motor unit recruitment and transmissions, along with delayed action potential spread across the muscle fibres and with synaptic delays, were mentioned as some of the reasons behind such RT delays [3]. Interestingly, studies also corroborate the connection of age-related changes to the maximal force (F_{max}) production. As the amount of force produced by a muscle depends on the aggregate of individual motor units, a reduction of the availability of motor units with age could limit the F_{max} along with promoting longer RT's [4]. Moreover, a decrease in volume of fast twitch fibres combined with an increase in non-contractile material in the muscles such as fat and connective tissues play a significant role in decreasing the force production with age [5].

Hence, considering the direct impact of RT and muscle forces on the driving capability of elderly people, the goal of this study is to explore the effect of the above-mentioned factors by way of steering and pedal force development of elderly subjects in Active Human Body Models (AHBMs) simulations.

II. METHODOLOGY

Experimental Data

The age bracket of 60 to 65 years was considered for the elderly population group. Experimental data for the trends of force production in the different age groups were obtained from [6], where an overall decrease of the average force of 45% was found in elderly people. Furthermore, a 25% lesser maximal force and a 40% lesser maximal shortening velocity in the elderly in comparison to younger people is described in [7]. For simulating a bracing scenario during pre-impact using a developed Finite Element (FE) AHBM with multiple muscles, it is essential to consider the activity of each muscle. To incorporate the reaction time delay, the authors referred to experimental data from [5], which reports an overall increase of Reaction time of 15ms in the elderly population.

Computational Modelling

All simulations were performed with the Total Human Model for Safety (THUMS) Adult Male 50th percentile Occupant model of version 5.02.1 acquired under academic license which, in its original state, is representative of a 30 to 40 year old average American male. It was subjected to the bracing scenario supplied as a validation catalogue alongside with the model, in which the subject pushes his right foot on a brake pedal and his hand on a steering wheel with a pre-defined muscle stimulation intensity. Changes were made to the settings of the LS-DYNA internal muscle material *MAT_156 [8] to account for the effects of ageing described above. The Peak Isometric Stress (PIS) value was reduced by 45% for all the muscles to incorporate the reduction of F_{max}. Modifications were also done to the contraction dynamics of the muscles by scaling down the Stress vs Strain

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Rate (SVR curve), which corresponds to the muscle's force-velocity relationship. Lastly, the muscle activation curves were modified to incorporate the RT delay of 15 ms.

III. INITIAL FINDINGS

Four distinct scenarios were considered to conduct a comparative study of the steering and pedal forces resulting from the applied bracing scenario and the reaction time required by the subjects to achieve the maximal force (F_{max}). (I) Young subject age 30 to 40 years with standard THUMS properties, (II) Elderly subject with reaction time delay, (III) Elderly subject with reduced F_{max} limit and adjusted contraction dynamics and (IV) Elderly subject with both reaction time delay, reduced F_{max} limit and adjusted contraction dynamics.

The time history curves of steering and pedal forces for each of the above-mentioned scenarios can be seen in Fig. 1 and Fig. 2.

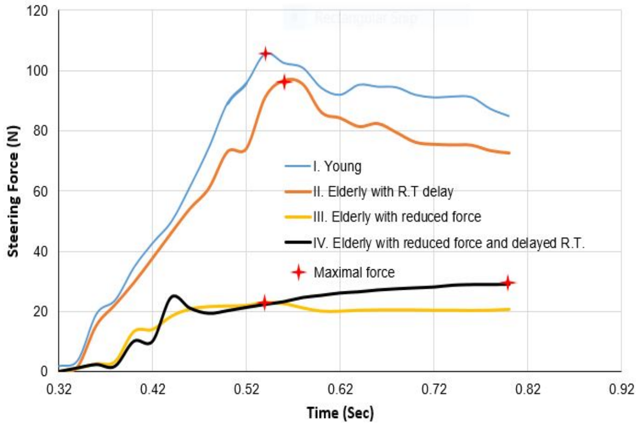

Fig. 1. Steering force for the 4 scenarios.

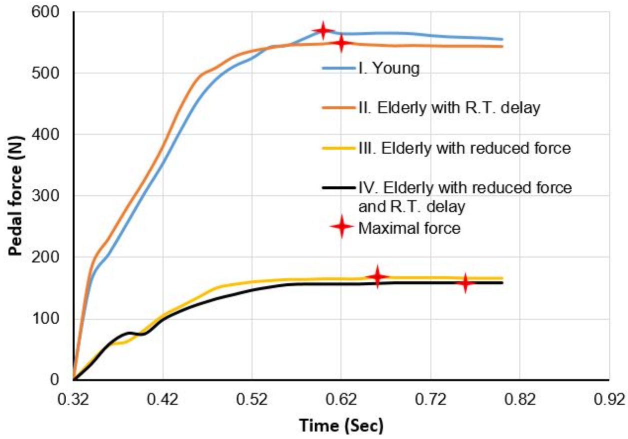

Fig. 2. Pedal force for the 4 scenarios.

IV. DISCUSSION

Multiple muscles in the human body act in synergy to balance or overcome the reaction forces of the environment. For driving the vehicle, they are the steering force of 105.4 N and pedal force of 568 N in younger subjects (Scenario I) [9], as evident from the curves shown in Fig. 1 and Fig. 2. As per expectation, it was observed that when subjected to a reduction of maximal force limit and scaled down SVR curves, the values of reaction pedal and steering forces of elderly subjects decreased by approximately 70% in comparison to their younger counterparts (Scenarios III and IV). After implementing a time delay for the activation curves of the elderly people, it could be seen that the time required by the elderly subjects to achieve maximal steering and pedal forces (marked in red in Fig.1 and Fig.2) was increased in comparison to the younger subjects. A time delay of about 20ms was found when the results for Scenario II were analysed. This time delay was also prominent when the HBM was subjected to both reaction time delay and reduced maximal force limit (Scenario IV). Similarly, the force was most reduced in Scenario IV. However, when we induced reaction time delay only, there was still an 8-10% reduction in force values and a change in curve characteristics which went beyond a simple temporal curve shift (Scenario II). This could be attributed to the fact that the difference in activity timing may impact the forces measured at the steering wheel, because some synergic muscle effects caused through otherwise synchronous activation, may be reduced.

It is evident through obtained results that incorporating the properties associated with an elderly subject, influences both the reaction time and the maximal forces which the driver can produce. This effect should be taken into account when developing active safety systems. However, to assess the driving capabilities of the elderly and to gain a more comprehensive perspective on the functioning of the combined effects of reaction time delay and reduced force-velocity relationship, further detailed research has to be conducted.

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