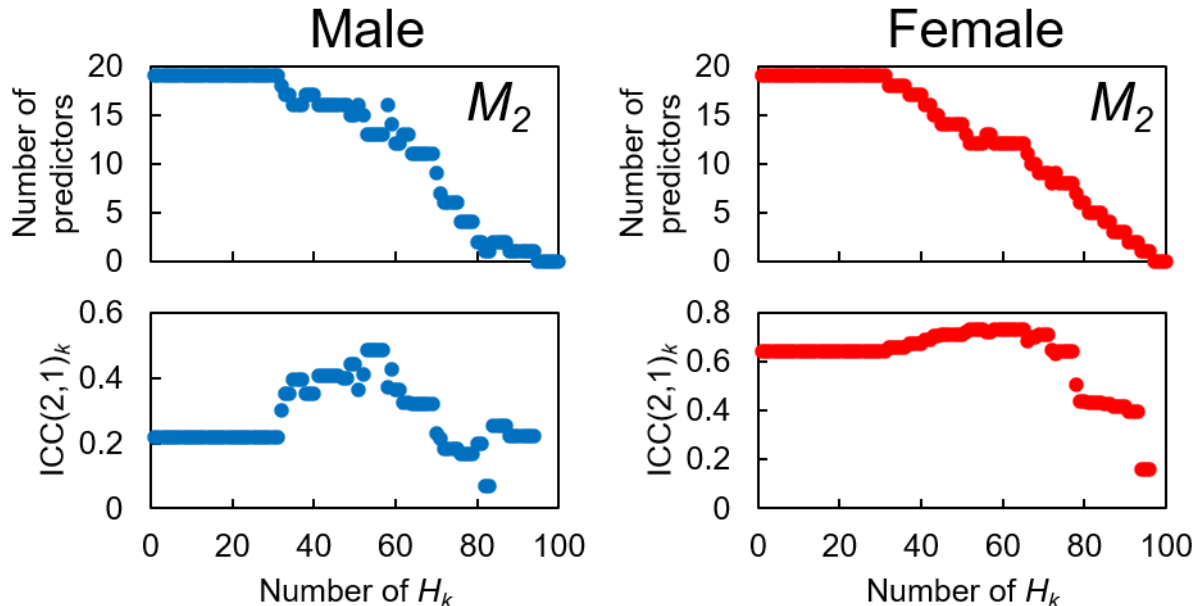


## Supplementary materials

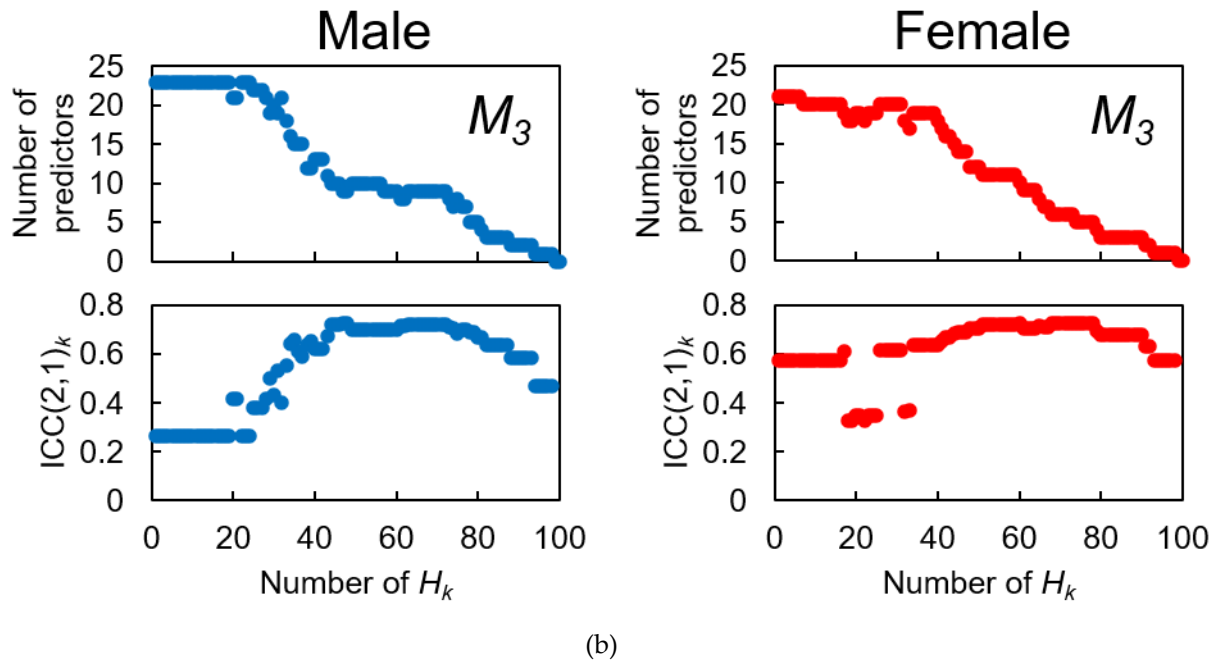
### 1. Details on selected predictors for $M_2$ and $M_3$

In this study, to construct a hand grip strength (HGS) estimation model from foot motion by using an in-shoe motion sensor (IMS), we first determined predictors from specific gait phases associated with HGS, called IMS predictors. Demographic data, including age, height, weight, and BMI (IPA predictors) and a number of gait parameters (GP predictors) were also used as auxiliary predictors to improve model precision. We selected the optimal predictor combination to construct optimal estimation model  $M_0$  via our original leave-one-subject-out least absolute shrinkage and selection operator (LOSO-LASSO) process (Fig. 3). To compare the effect of our method, especially the effect of the IMS predictors, models were derived from three other patterns of predictor combinations.  $M_1$ : gait speed (GP02),  $M_2$ :  $M_1$  plus other GPs in one stride, and  $M_3$ :  $M_2$  plus IPAs were also constructed and evaluated for comparison. Here,  $M_1$  had only one predictor; thus, we directly conducted linear regression.  $M_2$  and  $M_3$  were optimized by the same process as  $M_0$ , as shown in Fig. 3(b). For each case, in the same way as  $M_0$ , all candidate models  $H_1$ – $H_{100}$  were also evaluated by leave-one-subject-out cross-validation (LOSOCV), and type (2, 1) of the intra-class correlation coefficient [ICC(2, 1)] was applied as the evaluation index. Each  $H_i$  had an ICC(2, 1) value, and the one with the highest AIC value was chosen as the optimal one.

The results showing the optimal predictor combination in  $M_2$  and  $M_3$  are shown in Figs. S1(a) and (b). The predictors selected for  $M_2$  and  $M_3$  are listed in Table S1.



(a)



**Figure S1.** Results of LOSO-LASSO analysis to determine (a)  $M_2$  and (b)  $M_3$ .

**Table S1.** Optimal predictor combination in  $M_2$  and  $M_3$ .

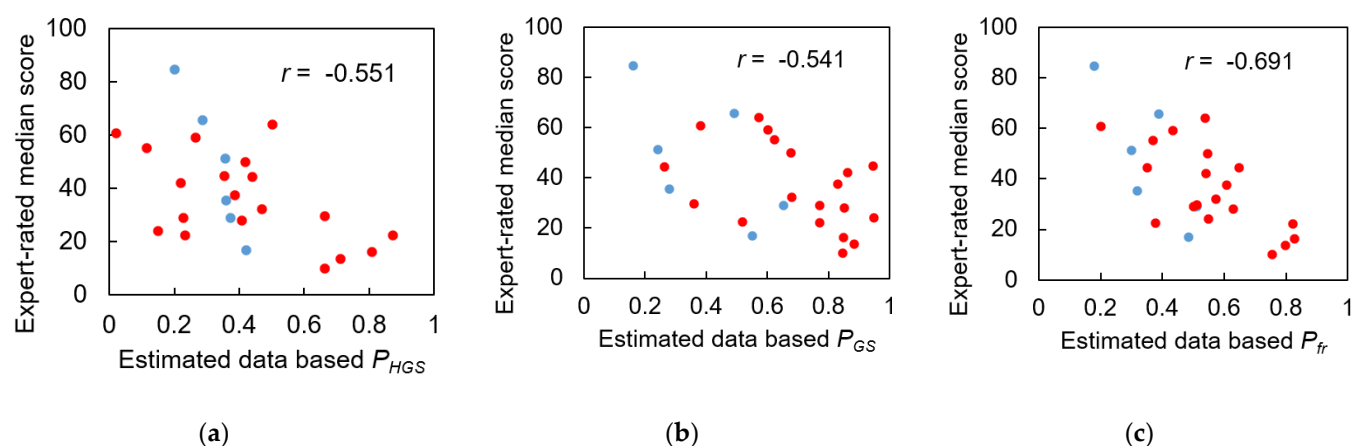
	Male	Female
$M_2$	GP01–03, GP05–08, GP10, GP13, GP15–17, GP20	GP01–03, GP06–10, GP13, GP15, GP16, GP20
$M_3$	Age, Weight, GP05, GP07, GP08, GP10, GP15, GP16, GP20	Age, Height, GP03, GP07, GP13, GP16

<sup>1</sup> Please note that GP01, GP05, and GP06 were normalized by subject height. GP11–14, GP19, and GP20 were normalized by time duration of one stride. GP15, GP16, and GP18 were normalized by maximum instantaneous walking velocity during swing phase.

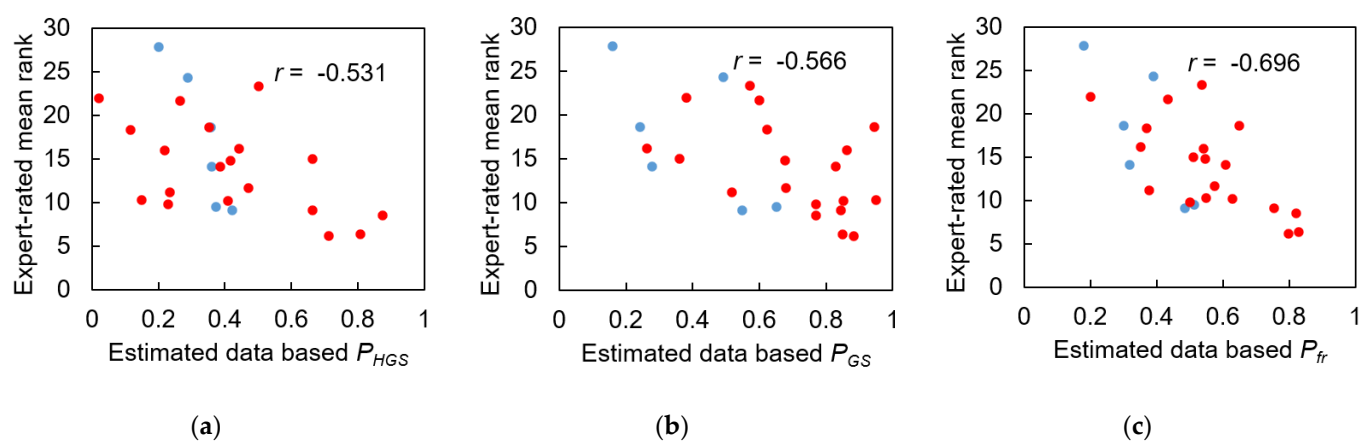
## 2. Correlation analysis between designed frailty risk score and expert-rated score in other patterns

The correlations between the expert-rated median score and the three types of performance scores calculated from the reference value and IMS-estimated value are shown in Fig. S2. The expert-rated median score was significantly correlated with the  $P_{HGS}$ ,  $P_{GS}$ , and  $P_{fr}$  with large effect sizes. The  $rs$  of  $P_{GS}$  and  $P_{fr}$  were higher than the pattern using the mean expert-rated score. In this study, for the mean expert-rated score of all subjects, the six values followed a normal distribution, but for several specific subjects, there were outliers in the six values. Therefore,  $rs$  may be increased by the excluding the outliers for these subjects.

The correlations between the expert-rated mean rank and the three types of performance scores calculated from the reference and IMS-estimated values are shown in Fig. S3. The rank reflected the relative frailty status of subjects in the cohort. The performance scores also had a large size effect correlation coefficient with the expert-rated mean rank. In addition, the  $rs$  of all three types of performance scores were higher than the pattern using the mean expert-rated score. However, please note that the rank was only meaningful for the cohort in this study; it cannot be expanded to other cohorts.



**Figure S2.** Correlations between expert-rated median score and three types of performance scores calculated from IMS-estimated value: (a)  $P_{HGS}$ , (b)  $P_{GS}$ , (c)  $P_{fr}$ .



**Figure S3.** Correlations between expert-rated mean rank and three types of performance scores calculated from IMS-estimated value: (a)  $P_{HGS}$ , (b)  $P_{GS}$ , (c)  $P_{fr}$ .