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Precision exercise medicine: Predicting unfavorable status and development in the 20-m shuttle run test performance in adolescence with machine learning.

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Supplementary information.

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Supplementary Document 1. List of all variables.

Variables			Range for continuous variables, and scale for nominal and ordinal variables	Unit	Notes	Measured
Background information						
		Age	9.2−15.3	years	Decimal age (counted from date of birth)	S 2013
		Sex	0, 1	boy = 0, girl = 1		S 2013
		Studying in a school which is part of the Finnish schools on the Move program	0, 1	no = 0, yes = 1		S 2013
Data from objective measurements						
	Accelerometry-based physical activity					
		Sedentary time	40−86	%	Percentage of device wearing time	S 2013
		Light physical activity	88−378	min · day^{-1}	Weighted mean value	S 2013
		Moderate-to-vigorous physical activity	9−163	min · day^{-1}	Weighted mean value	S 2013
		Continuous sedentary time	15−343	min · day^{-1}	Weighted mean value of continuous sedentary time longer than 10min	S 2013
		Counts	111−1211	cpm · day^{-1}	Counts per minute per day. Weighted mean value	S 2013
	Physical fitness					
		Performance in the 20-m shuttle run test at baseline	3−109	laps	Laps run until voluntary exhaustion. Protocol by Finnish Move! – monitoring system for physical functional capacity (slightly modified version from the EUROFIT protocol)	S 2013
		5-leaps test	4.5−12.2	m	Distance measured in 0.1 m accuracy	S 2013
		Push-ups	0−63	repetitions	Within 1-minute	S 2013
		Curl-up	0−75	repetitions	Maximum of 75 repetitions	S 2013
		Flexibility score	0−4	sum	Sum of four flexibility assessments	S 2013
		Throwing-catching combination test	0−20	repetitions	Maximum of 20 repetitions	S 2013

Antropometrics and body compositon				
Height	131.3−184.9	m	Stature measured in 0.1 cm accuracy	S 2013
Visceral Fat	5.0−223.7	cm^2	Estimation by bioelectric impedance	S 2013
Weight	24.3−102.8	kg	Measured in 0.1 kg accuracy	S 2013
Skeletal muscle mass	10.6−39.5	kg	Estimation by bioelectric impedance	S 2013
Body fat percentage	3.0−47.9	%	Estimation by bioelectric impedance	S 2013
BMI	12.8−36.3	kg·m^{-2}		S 2013
Waist circumference	45.0−118.2	cm		S 2013
BMI classification	1−3	Normal weight = 1, overweight = 2, or obese = 3.	Classification by Cole scale	S 2013
Data from self-assessment questionnaires				
Pubertal status	0−5	pre-pubertal = 0, fully matured = 5.	Classification by Tanner scale. From pre-pubertal to fully matured.	S 2013
Perceived health	1−4	very good = 1, poor = 4	From very good to poor. ICC: 0.575	S 2013
Perceived fitness	1−4	very good = 1, poor = 4	From very good to poor. ICC: 0.678	S 2013
Days with physical activity for at least 60min/day during the previous 7 days	0−8	1 = 0 days, 8 = 7 days	From 0–7 days. ICC: 0.590	S 2013
Amount of moderate-to-vigorous physical activity during leisure-time	0−6	1 = not at all, 6 = 7 hours or more	From 0 to ≥7 h/week. ICC: 0.752	S 2013
Participation to physical activity clubs in schools	1−3	not at all = 1, regularly = 3	From not at all to regularly. ICC:0.704	S 2013
Participation to sport club practices	1−4	not at all = 1, regularly = 3	From not at all to regularly. ICC: 0.876	S 2013
Participation to sport competitions or matches	1−5	not at all = 1, regularly = 3	From not at all to regularly. ICC: 0.865	S 2013
Bedtime on schooldays	1−7	From 21:00 = 1, to 24:00 or later = 7	From 21:00 to 24:00 or later. Assessed with half hour intervals. ICC: 0.876	S 2013

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		Tiredness on school mornings	1−4	never = 1, 4 times/week on more = 4	From never to 4 times/week on more. ICC: 0.679	S 2013
		Eating breakfast during school week	1−4	every day = 1, rarely = 4	From every day to rarely. ICC: 0.621	S 2013
		Smoking habits	1−5	not at all = 1, once a day or more = 5	From not at all to once a day or more.	F 2013
		Alcohol consumption	1−9	not at all 1, every day = 5	From not at all to every day.	F 2013
		Unhealthy diet index	1−7	not at all = 1, more than once a day = 7	An index score for eating unhealthy foods from not at all to more than once a day (an average score of eating sweets or chocolate, sugary soft drinks, hamburgers or hot dogs, crisps, and pizza).	F 2013
		Healthy diet index	1−7	not at all = 1, more than once a day = 7	An index score for eating healthy foods from not at all to more than once a day (an average of eating fruits and vegetables).	F 2013
		School enjoyment	1−4	a lot = 1, not at all = 4	From a lot to not at all. ICC: 0.752	S 2013
		School strain	1−4	not at all =1, a lot = 4	From not at all to a lot. ICC: 0.608	S 2013
		Being bullied at school	1−5	not at all =1, several times a week = 5	Being bullied within a last couple of months from not at all, to several times a week. ICC: 0.428	S 2013
		Perceived social status in school	1−10	10 = 1, 1 = 10	A ladder scale: on the high end students who are appreciated most (10, coded as 1). At low end students who nobody appreciates (1, coded as 10). ICC: 0.779	S 2013
		Perceived societal status of the family	1−10	10 = 1, 1 = 10	A ladder scale: on the high end people who most people appreciate (10, coded as 1). At low end people who most of the people don't appreciate (1, coded as 10). ICC: 0.700	S 2013
		Life enjoyment	1−7	4 = 1, 10 = 7	Overall enjoyment of current life (in school grade points 4-10). ICC: 0.722	S 2013

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	Parents willing to help if problems at school	1−5	totally agree = 1, totally disagree = 5	From I totally agree to I totally disagree. ICC: 0.661	S 2013
	Parents are willing to discuss with teachers	1−5	totally agree = 1, totally disagree = 5	From I totally agree to I totally disagree. ICC: 0.709	S 2013
	Parents encourage to success in school	1−5	totally agree = 1, totally disagree = 5	From I totally agree to I totally disagree. ICC: 0.527	S 2013
	Parents interested what happens in school	1−5	totally agree = 1, totally disagree = 5	From I totally agree to I totally disagree. ICC: 0.675	S 2013
	Parents willing to help with schoolwork	1−5	totally agree = 1, totally disagree = 5	From I totally agree to I totally disagree. ICC: 0.624	S 2013
Data from registers					
	Grade point average	5.5−9.9	4.0−10.0	The average of teacher's rated academic scores including native language, foreign language, physics, chemistry, mathematics, biology, geography, religion, philosophy, history, music, art, technical or textile skills, and physical education.	S 2013
	Grade point in Physical Education	6−10	4.0−10.0	Grade point in PE. Teacher's evaluation.	S 2013
Outcome variables					
	Performance in the 20-m shuttle run test at follow-up (task 1)		laps	Performance in the 20-m shuttle run test in follow-up measurements	S 2015
	Change in 20-m shuttle run result (task 2)		laps	Absolute difference between baseline (S 2013) and follow-up measurements (S 2015)	

cpm, counts per minute; S 2013, spring semester 2015; F 2013, fall semester 2013; S 2015, spring semester 2015, ICC: Intraclass correlation coefficient of the variable in a test-retest analysis.(n=181)

Supplementary Document 2. Code package

The MATLAB script and functions employing the RF classifier can be downloaded from the following address as a compressed zip file:

http://users.jyu.fi/~iltaraut/Supplement_2.zip

The password for the zip file is "BJSM_Supplement2" without quotes. For Windows, a separate file archiver, such as 7-Zip, WinRAR or WinZip, might

be needed to open the encrypted archive.

Supplementary Document 3. Further description of predictive modelling

Training and prediction

In random forest (RF) it is important that the individual trees are uncorrelated because low correlation helps to protect the forest from misclassifications.

This goal is achieved in RF by two techniques: bootstrap aggregation (aka bagging) and random feature selection. Firstly, bagging refers to taking a

bootstrap sample with replacement from the training data when forming a new tree, the result being a forest where each tree is formed using a different

data sample. A new data sample to be predicted is then shown to the forest, the final prediction being the average prediction of individual prediction or,

in the case of classification, the most popular prediction among the trees. Secondly, random feature selection is a technique where, instead of all the

features, only a limited random set of features is available for each tree. This feature set is picked up randomly each time a new tree is grown (1,2).

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As an additional note regarding the feature importance estimation in RF, it can be said that if the feature contains important information for classification, randomly permuting the feature values will increase the classification error. Moreover, if the feature does not contain information for classification, randomly permuting the values will not influence the classification error (1).

The training phase included procedures to optimize 20MSRT prediction with RF and the training data. Bayesian optimization (3) was employed to estimate the optimal hyperparameters (e.g. the method parameters that must be defined beforehand) for RF. The F1-score measure, which balances the precision and sensitivity of the classifier by computing their harmonic mean, was used as the optimization target for the RF out-of-bag samples. It is defined as

$$F1 = 2 \times \frac{precision \times sensitivity}{precision + sensitivity},$$

where

$$precision = \frac{TP}{TP + FP},$$

and

$$sensitivity = \frac{TP}{TP + FN}.$$

In the above equations, TP (true positives) refers to the number of correctly detected lowest tertile cases. FP (false positives) is the number of cases incorrectly identified as belonging to the lowest tertile and FN (false negatives) is the number of cases incorrectly identified as belonging to the second

or third tertile. Since the Bayesian optimization aims to minimize the given objective, the final target for optimization was $1 - F1$. In addition to abovementioned equations, specificity, defined as

$$specificity = \frac{TN}{TN + FP},$$

was employed as a performance metric.

In order to make the standard binary classification measures usable for a three class classification problem, the optimization was employed specifically for the lowest tertile group, i.e. the F1-score to be optimized was calculated by comparing the lowest tertile group to the two other groups. After training, a testing phase was implemented where the validity of the findings was tested against the left-out fold in 10-fold CV. During this phase, the measures used to estimate the prediction performance were AUC, sensitivity and specificity. Similarly to the F1-score employment before, these measures were calculated using the lowest tertile vs. other tertiles approach.

For handling the missing values in data, the original random forest method suggested two ways of imputing the missing values (1). The TreeBagger implementation in MATLAB employs a surrogate decision split especially for handling the missing values in data. When the surrogate decision splits flag is set to "on", a similar or correlated predictor value is used instead of the missing value.

Four RF hyperparameters in MATLAB's TreeBagger function were optimized:

1. *NumPredictorsToSample*: The number of variables to select at random for each decision split (range to search was from 1 to 47, which was the total number of usable variables)

2. *MinLeafSize*: The minimum number of observations per tree leaf (range from 1 to 20).

3. *MaxNumSplits*: The maximal number of decision splits (range from 1 to 20).

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4. *Surrogate*: Surrogate decision splits flag (options included on, off and all).

Static modified RF parameters included:

1. The number of trees in the forest was set to 500.

2. *Studying in a school which is part of the Finnish schools on the Move program* was set as a categorical variable (option *CategoricalPredictors*).

3. Algorithm used to select the best split predictor (option *PredictorSelection*) was set to *interaction-curvature*.

In addition, two static parameters were modified in MATLAB's Bayesian optimization (bayesopt) function:

1. *MaxObjectiveEvaluations* was set to 100, meaning that there are one hundred iterations to search for optimal hyperparameters, after which the optimization is terminated.

2. *AcquisitionFunctionName* was set to *expected-improvement-plus*.

Supplementary Table 1. List of variables that were age-adjusted using linear regression

5-leaps test
Alcohol consumption
BMI
Body fat percentage
Continuous sedentary time
Counts
Curl-up
Flexibility score
Healthy diet index
Height
Light physical activity
Moderate-to-vigorous physical activity
Parents encourage to success in school

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Parents interested what happens in school
Parents willing to discuss with teachers
Parents willing to help if problems at school
Parents willing to help with schoolwork
Performance in the 20-m shuttle run test at baseline
Pubertal status classification
Push-ups
Sedentary time
Skeletal muscle mass
Smoking habits
Throwing-catching combination test
Unhealthy diet index
Visceral fat
Waist circumference
Weight

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Supplementary Document 4. Results of the ROC analysis and random forest predictor importance estimates

The following four tables include the results for two separate analyses. The first one is the ROC analysis. For each variable, an Area Under Curve (AUC) value and the associated direction is reported. In the ROC analysis phase, the AUC value is estimated for each of the variables separately, by using one variable at a time as the independent variable and performance in the **20-m shuttle run test at follow-up** as the dependent variable. There are two types of arrows in the tables. They should be interpreted in the following manner:

- ↘: The *lower* the variable value, the higher is the probability of the student belonging to the lowest tertile.
- ↗: The *higher* the variable value, the higher is the probability of the student belonging to the lowest tertile.

The second analysis, performed completely separately from the ROC analysis described above, is the delta error mean value and its p value for each variable. These results originate from the random forest's feature importance estimate analysis.

Girls: Prediction of 20MSRT performance at follow-up

Variable	ROC analysis		Random forest feature importance	
	AUC	Associated direction	Delta error mean	*P*
Performance in the 20-m shuttle run test at baseline	0.822	↘	1.778	0.00013
Body fat percentage	0.736	↗	0.295	4.98E-09
5-leaps test	0.714	↘	0.312	4.00E-08
Grade point in Physical Education	0.713	↘	0.166	0.00012
Grade point average	0.708	↘	0.199	1.86E-05
Push-ups	0.702	↘	0.131	0.00027
Visceral fat	0.690	↗	0.135	1.09E-05
Moderate-to-vigorous physical activity	0.652	↘	0.125	0.00344
BMI	0.645	↗	0.030	0.06571
Counts	0.643	↘	0.274	2.72E-05
Curl-up	0.622	↘	0.009	0.62857
Flexibility score	0.614	↘	0.041	0.04908

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Waist circumference	0.614	↗	-0.020	0.08999
Parents willing to help with schoolwork	0.597	↗	-0.012	0.40727
BMI classification	0.596	↗	-0.018	0.03220
Weight	0.586	↗	0.011	0.25740
Life enjoyment	0.584	↘	-0.007	0.46964
Eating breakfast during schoolweek	0.582	↗	-0.008	0.24529
Unhealthy diet index	0.580	↗	0.016	0.34412
Days with PA for at least 60min/day during the previous 7 days	0.578	↘	0.020	0.23977
Participation to sport competitions or matches	0.578	↘	0.143	3.91E-05
Being bullied at school	0.576	↗	0.004	0.74703
Parents interested what happens in school	0.570	↗	0.026	0.07335
Amount of moderate-to-vigorous physical activity during leisure-time	0.570	↘	0.006	0.55980
Throwing-catching combination test	0.565	↘	0.050	0.05235
Perceived social status at school	0.564	↗	0.025	0.01456
Sedentary time	0.564	↗	0.073	0.00948
Parents encourage to success in school	0.563	↗	-0.021	0.25787
Parents willing to discuss with teachers	0.563	↗	-0.009	0.68365
Healthy diet index	0.560	↘	-0.017	0.21666
Participation to sport club practices	0.551	↘	0.033	0.02458
Studying in a school which is part of the Finnish schools on the Move program	0.547	↗	-0.015	0.13847
Light physical activity	0.544	↘	0.017	0.27079
Parents willing to help if problems at school	0.543	↗	-0.018	0.20185
Alcohol consumption	0.537	↗	0.023	0.10378
Height	0.536	↘	0.007	0.60257
Smoking habits	0.531	↗	-0.002	0.81458
Continuous sedentary time	0.531	↗	0.006	0.65614
School strain	0.529	↗	-0.003	0.73604
Perceived fitness	0.529	↗	0.008	0.42683

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Perceived health	0.529	↗	0.000	1
Tiredness on school mornings	0.521	↗	-0.006	0.35962
Age	0.518	↗	n/a	n/a
Skeletal muscle mass	0.516	↘	0.029	0.19240
Bedtime on schooldays	0.516	↗	-0.015	0.09695
Perceived social status of the family	0.513	↗	-0.013	0.15855
School enjoyment	0.513	↗	0.006	0.62529
Pubertal status	0.512	↘	0.009	0.39893
Participation to physical activity clubs in school	0.503	↘	-0.004	0.34344

Girls: Prediction of development in the 20MSRT within a subgroup

Variable	ROC analysis		Random forest feature importance	
	AUC	Associated direction	Delta error mean	*P*
Grade point average	0.675	↘	0.211	5.29E-07
Body fat percentage	0.632	↗	0.076	0.00885
Unhealthy diet index	0.628	↗	0.146	0.00014
Grade point in Physical Education	0.627	↘	0.034	0.04429
Counts	0.626	↘	0.073	0.00514
Life enjoyment	0.615	↘	0.054	0.00174
Sedentary time	0.603	↗	-0.017	0.45995
Visceral fat	0.596	↗	0.118	0.00135
Studying in a school which is part of the Finnish schools on the Move program	0.594	↗	-0.015	0.29645
Perceived social status at school	0.589	↗	0.036	0.01460
Moderate-to-vigorous physical activity	0.587	↘	0.028	0.24065

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Being bullied at school	0.584	↗	0.015	0.53917
Light physical activity	0.583	↘	-0.031	0.07665
5-leaps test	0.582	↘	0.088	0.00094
Participation to sport club practices	0.567	↘	-0.014	0.38971
BMI	0.567	↗	-0.005	0.83415
BMI classification	0.561	↗	-0.007	0.56828
Days with PA for at least 60min/day during the previous 7 days	0.560	↗	-0.033	0.03430
Bedtime on schooldays	0.560	↗	0.064	0.03029
Flexibility score	0.560	↘	0.033	0.14350
Parents encourage to success in school	0.560	↗	-0.051	0.00169
School strain	0.558	↗	-0.004	0.75310
Eating breakfast during schoolweek	0.555	↗	-0.006	0.72089
Continuous sedentary time	0.552	↗	-0.015	0.22174
Push-ups	0.551	↘	-0.021	0.22555
Parents interested what happens in school	0.550	↗	0.012	0.35171
Tiredness on school mornings	0.548	↘	0.012	0.42458
Healthy diet index	0.546	↘	-0.044	0.03057
Participation to physical activity clubs in school	0.544	↗	0.000	0.97885
Pubertal status	0.537	↗	-0.018	0.19099
Weight	0.536	↗	-0.015	0.40546
School enjoyment	0.532	↘	0.002	0.86673
Parents willing to help with schoolwork	0.532	↗	-0.060	0.00028
Perceived social status of the family	0.532	↗	-0.018	0.32814
Age	0.528	↗	n/a	n/a
Curl-up	0.523	↘	0.017	0.32803
Throwing-catching combination test	0.520	↘	-0.060	9.54E-05
Skeletal muscle mass	0.518	↘	-0.007	0.78502

Perceived fitness	0.518	↗	-0.014	0.38310
Height	0.517	↘	-0.015	0.38247
Alcohol consumption	0.516	↗	0.018	0.39879
Waist circumference	0.516	↗	-0.047	0.01471
Participation to sport competitions or matches	0.511	↗	0.021	0.24405
Parents willing to discuss with teachers	0.510	↗	-0.022	0.03401
Smoking habits	0.506	↗	-0.031	0.16880
Perceived health	0.505	↗	-0.012	0.49579
Parents willing to help if problems at school	0.503	↗	0.002	0.94303
Performance in the 20-m shuttle run test at baseline	0.503	↘	-0.008	0.63170
Amount of moderate-to-vigorous physical activity during leisure-time	0.502	↗	-0.001	0.94632

Boys: Prediction of 20MSRT performance at follow-up

Variable	ROC analysis		Random forest feature importance	
	AUC	Associated direction	Delta error mean	*P*
Performance in the 20-m shuttle run test at baseline	0.770	↘	1.707	3.41E-07
Body fat percentage	0.740	↗	0.230	4.26E-07
Grade point in Physical Education	0.734	↘	0.163	3.20E-05
Push-ups	0.717	↘	0.316	4.06E-08
Visceral fat	0.715	↗	0.213	7.89E-06
5-leaps test	0.667	↘	0.194	3.61E-05

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Amount of moderate-to-vigorous physical activity during leisure-time	0.648	↘	0.103	1.73E-05
Curl-up	0.647	↘	0.090	0.00144
Counts	0.647	↘	0.020	0.23825
Moderate-to-vigorous physical activity	0.645	↘	0.042	0.01995
Participation to sport competitions or matches	0.641	↘	0.059	0.00140
BMI	0.635	↗	0.061	0.00502
Waist circumference	0.635	↗	0.079	0.00025
Grade point average	0.632	↘	0.069	0.01477
Throwing-catching combination test	0.631	↘	0.113	0.00031
Participation to sport club practices	0.630	↘	0.261	6.02E-07
Sedentary time	0.610	↗	0.013	0.19573
Perceived fitness	0.610	↗	0.036	0.00699
Light physical activity	0.598	↘	-0.020	0.03750
Days with PA for at least 60min/day during the previous 7 days	0.594	↘	0.040	0.00559
BMI classification	0.593	↗	0.027	0.17184
Weight	0.587	↗	0.063	0.00074
Life enjoyment	0.587	↘	0.026	0.04242
Perceived health	0.584	↗	0.009	0.15261
Flexibility score	0.581	↘	0.016	0.32376
Studying in a school which is part of the Finnish schools on the Move program	0.560	↗	0.027	0.28360
Perceived social status at school	0.550	↗	-0.001	0.87506
Continuous sedentary time	0.547	↗	0.001	0.89948
Parents interested what happens in school	0.543	↘	-0.006	0.49984
Unhealthy diet index	0.537	↘	0.006	0.38546
Participation to physical activity clubs in school	0.536	↘	0.009	0.17264

School strain	0.531	↘	0.003	0.56020
Being bullied at school	0.530	↗	0.004	0.75491
Alcohol consumption	0.524	↗	-0.003	0.81026
Bedtime on schooldays	0.524	↗	0.047	0.05392
Eating breakfast during schoolweek	0.517	↗	0.004	0.68718
Parents willing to discuss with teachers	0.515	↘	-0.039	0.00899
School enjoyment	0.515	↗	-0.006	0.47068
Smoking habits	0.514	↘	-0.015	0.23412
Skeletal muscle mass	0.512	↘	-0.003	0.83889
Parents encourage to success in school	0.511	↗	0.000	0.96685
Parents willing to help with schoolwork	0.510	↗	0.058	0.04542
Perceived social status of the family	0.510	↗	0.000	0.96422
Healthy diet index	0.506	↘	-0.025	0.05273
Tiredness on school mornings	0.504	↘	0.000	0.96828
Height	0.503	↗	-0.009	0.63760
Parents willing to help if problems at school	0.501	↘	0.012	0.34387
Age	0.501	↘	n/a	n/a
Pubertal status	0.500	↗	0.026	0.21019

Boys: Prediction of development in the 20MSRT within a subgroup

Variable	ROC analysis		Random forest feature importance	
	AUC	Associated direction	Delta error mean	*P*
Performance in the 20-m shuttle run test at baseline	0.587	↗	-0.008	0.67323
Studying in a school which is part of the Finnish schools on the Move program	0.586	↗	-0.008	0.52483

Days with PA for at least 60min/day during the previous 7 days	0.585	↘	-0.013	0.45165
Waist circumference	0.580	↘	-0.048	0.00181
Unhealthy diet index	0.568	↗	-0.062	0.00028
Skeletal muscle mass	0.567	↘	-0.022	0.20299
Amount of moderate-to-vigorous physical activity during leisure-time	0.566	↘	-0.017	0.36835
Perceived social status at school	0.564	↘	-0.055	0.00507
Pubertal status	0.563	↘	-0.009	0.65035
Perceived fitness	0.558	↘	-0.023	0.10348
Perceived health	0.558	↗	-0.028	0.14923
Weight	0.556	↘	-0.029	0.09146
Being bullied at school	0.552	↗	0.049	0.00299
Parents interested what happens in school	0.552	↘	-0.024	0.28071
Height	0.547	↘	-0.066	3.11E-05
BMI	0.545	↘	-0.081	5.79E-05
Counts	0.545	↗	0.025	0.23951
Life enjoyment	0.544	↗	-0.014	0.42964
Moderate-to-vigorous physical activity	0.543	↗	0.044	0.05773
Healthy diet index	0.542	↗	-0.048	0.01030
Perceived social status of the family	0.531	↘	-0.015	0.33614
Grade point in Physical Education	0.529	↗	-0.008	0.55866
Parents encourage to success in school	0.527	↘	-0.041	0.03742
Continuous sedentary time	0.527	↘	-0.068	0.00019
Light physical activity	0.526	↘	0.047	0.01658
Grade point average	0.525	↘	-0.009	0.36841
Flexibility score	0.524	↗	-0.019	0.24104
Body fat percentage	0.520	↗	-0.037	0.13794
BMI classification	0.519	↘	-0.002	0.91938

Precision exercise medicine: Predicting unfavorable status and development in the 20-m shuttle run test performance in adolescence with machine learning.
Laura Joensuu, Ilkka Rautiainen, Sami Äyrämö, Heidi J Syväoja, Jukka-Pekka Kauppi, Urho M Kujala, Tuija H Tammelin (2021)
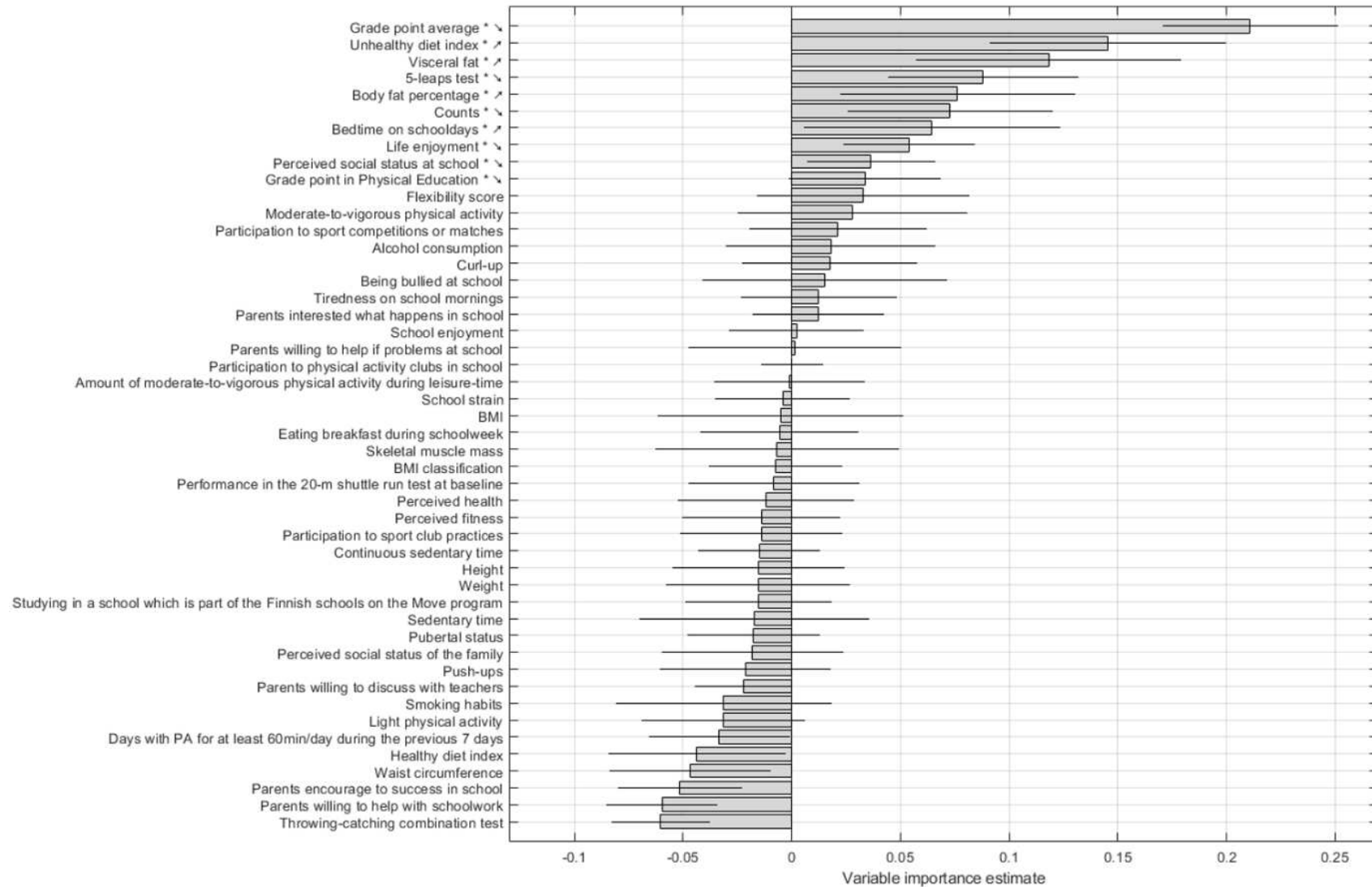
Parents willing to discuss with teachers	0.518	↗	-0.092	3.79E-05
5-leaps test	0.517	↘	-0.039	0.00998
Push-ups	0.515	↘	-0.086	2.05E-06
Sedentary time	0.515	↘	-0.033	0.15816
Smoking habits	0.515	↘	-0.068	2.18E-05
Throwing-catching combination test	0.513	↗	-0.088	0.00039
Curl-up	0.512	↘	-0.088	2.82E-05
School enjoyment	0.512	↗	-0.024	0.00064
Parents willing to help with schoolwork	0.509	↗	-0.027	0.03858
Bedtime on schooldays	0.508	↘	-0.003	0.84277
Age	0.508	↘	n/a	n/a
School strain	0.507	↘	-0.008	0.66655
Participation to sport competitions or matches	0.506	↘	-0.047	0.00920
Participation to physical activity clubs in school	0.506	↘	-0.021	0.21880
Visceral fat	0.506	↘	-0.049	0.01872
Parents willing to help if problems at school	0.505	↗	-0.019	0.22798
Tiredness on school mornings	0.505	↘	-0.007	0.55928
Eating breakfast during schoolweek	0.505	↗	0.024	0.10340
Alcohol consumption	0.504	↗	-0.070	0.00196
Participation to sport club practices	0.502	↘	-0.032	0.01033

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Supplementary Document 5. Best predictors for development

The best predictors for 20MSRT development included ten baseline variables in girls and two in boys (Supplemental Figures below). In girls, low academic scores (GPA ($P < 0.001$), and grade point in physical education, ($P = 0.044$), frequent consumption of unhealthy foods ($P < 0.001$), high markers of adiposity (visceral fat ($P = 0.001$), and body fat percentage ($P = 0.009$)), low performance in 5-leaps test ($P < 0.001$), low amount of accelerometry-based counts ($P = 0.005$), late bedtime ($P = 0.030$), low life enjoyment ($P = 0.002$), and low perceived social status in school ($P = 0.015$), all predicted below average age- and sex-adjusted 20MSRT development in initially below-median performers.

In boys, the overall prediction performance was statistically non-significant in boys ($P = 0.1080$), with only two statistically significant predictive variables observed (Figure below): increased frequency of being bullied at school ($P = 0.003$), and low amount of accelerometry-based light physical activity ($P = 0.017$).

Girls

Supplemental material

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Boys