



QTUG™

RESULTS INTERPRETATION AND GUIDANCE

VERSION 4.1

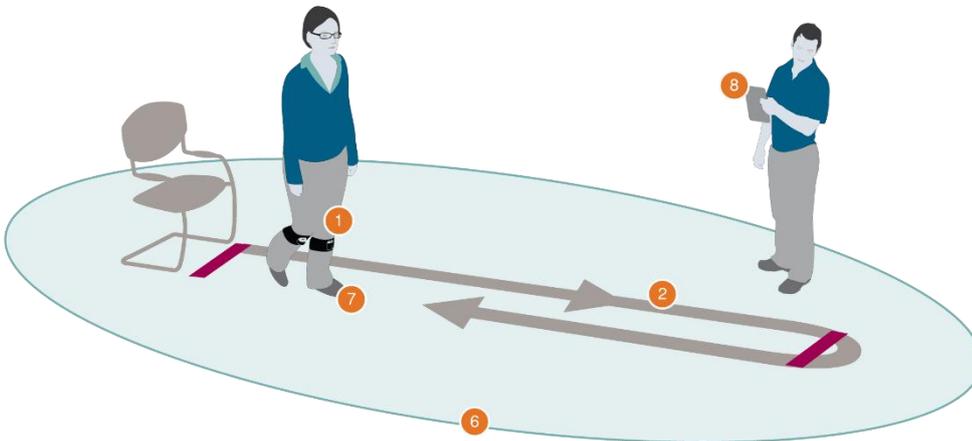
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QTUG™ TEST

Each patient completes a Timed Up and Go (TUG) test as shown below

SETUP GUIDELINES



1. Sensors are affixed to the mid-point of the anterior shank (shin) using elasticized bandages.
2. 3 metre distance must be **accurately measured** to ensure QTUG™ operates correctly.
3. The recommended instructions to give the patient prior to performing the test should be as follows: **“Complete the TUG test as fast as safely possible”**.
4. Mobility aids **are not recommended** to be used during the test.
5. Height and weight should be measured before **each** test.
6. Underfoot conditions should be controlled (e.g. no loose carpeting).
7. Sensible footwear (e.g. no high-heels) should be worn during the test.
8. The mobility of **patients not at risk of falls** can be assessed by selecting ‘falls mode’ as off.

TEST RESULTS

Categories of results produced by QTUG™.

TUG test time

Time taken to complete the TUG test.

Falls risk estimate (FRE)

Statistical risk of falls based on a model derived from community dwelling older adults. If Falls questionnaire is enabled, these data are used to improve the FRE.

Frailty estimate (FE)

Statistical estimate of patient’s frailty level (as defined by Fried’s frailty phenotype), based on a model of community dwelling older adults. If Falls questionnaire is enabled, these data are used to improve the FE.

Mobility risk scores

Mobility scores are calculated to identify mobility impairment by grouping the measured QTUG mobility parameters into five functional categories: walking, variability, symmetry, transfers and

turning. A high mobility score (>70%) indicates a that the patient may have a problem in the functional area highlighted.

Detailed results

Comprehensive quantitative assessment of mobility including temporal and spatial gait parameters, gait variability and gait symmetry.

Falls questionnaire

Optional questions on patient's falls history based on AGS/BGS falls questionnaire. Enabling this questionnaire will improve the falls risk estimate provided by QTUG™.

Clinical risk factors

Clinical fall risk factors reported in completing the falls questionnaire.

Advice screen

Advice and recommendations based on the clinical risk factors reported by the patient.

Historical trends

Trends of FRE, FE and TUG time over time for a given patient.

PARAMETER DEFINITION

Definition of mobility parameters produced by QTUG™

Note: A section **NORMAL RANGES FOR REFERENCE DATA** is included later in the document. This section outlines parameter averages, ranges as well as unusual and warning values.

Parameter definition	Description
Falls risk estimate (%)	<p>Statistical risk of having a fall (defined for community dwelling older adults over 60 years of age).</p> <p>Values below 50% are considered low risk. Values between 50 and 70% are considered medium risk. Values above 70% are high risk while values above 90% are considered very high risk.</p>
Frailty estimate (%)	<p>Statistical estimate of frailty level (defined using Fried's phenotype for patients over 60 years of age)</p> <p>Values below 50% are considered non-frail. Values between 50 and 70% are considered transitional. Values above 70% are frail while values above 90% are considered very frail.</p>
TUG test time (s)	<p>Recording time for entire TUG test as recorded using body-worn sensors.</p> <p>Longer TUG times are associated with increased risk of falls^{1,2}. Longer TUG times have also been associated with increased frailty^{3,4}.</p>

Mobility risk scores

Speed score (%)	<p>Assessment of parameters relating to walking speed.</p> <p>A high Speed score (>70%) is associated with slow walking speed. Slow walking speed is associated with falls, frailty, mortality and morbidity.</p>
Turn score (%)	<p>Assessment of patient's ability to turn.</p> <p>A high turn score (>70%) indicates poor turn performance. Problems turning are associated with impaired balance and falls risk.</p>
Transfer score (%)	<p>Assessment of sit to stand and stand to sit transfers.</p> <p>A high Transfer score (>70%) indicates difficulty in transferring to and from a seated position. This can be associated with poor core and lower limb strength and is associated with falls.</p>
Variability score (%)	<p>Assessment of gait variability.</p> <p>A high Variability score (>70%) indicates a high level of gait variability which is associated with gait impairment and falls risk.</p>
Symmetry score (%)	<p>Assessment of gait asymmetry.</p> <p>A high Symmetry score (>70%) indicates a high level of gait asymmetry. Gait asymmetry is associated with neurological disorders and mobility impairment.</p>

Spatial gait parameters

Average stride velocity (cm/s)

Average gait (walking) speed during TUG test.

Lower values of gait speed (stride velocity) are associated with increased falls risk and morbidity as well as with survival⁵. Gait velocity can be improved through targeted physiotherapy.

Stride velocity variability (%)

Variation in walking speed during TUG test.

Too much or too little variability in gait velocity is associated with increased falls risk⁶. High gait velocity variability could indicate unsteady gait.

Stride velocity asymmetry (%)

Gait symmetry index for gait velocity: difference between right and left divided by average of right and left, expressed as a percentage. Minus values indicate left leg asymmetry.

Negative values indicate left leg asymmetry in gait velocity. Large negative or positive values indicative asymmetric or uneven gait.

Average stride length (cm)

Mean stride length during TUG test.

Shorter stride length values are associated with increased falls risk. Shorter stride length can also be an indicator of Parkinson's as well as other neurological disorders such as multiple sclerosis. Stride length is strongly correlated with gait velocity.

Stride length variability (%)

Coefficient of variability in stride length over TUG test.

Increased stride length variability has been associated with increased risk of falls.

Stride length asymmetry (%)

Gait symmetry index for stride length: difference between right and left divided by average of right and left, expressed as a percentage. Minus values indicate left leg asymmetry.

Negative values indicate left leg asymmetry in stride length. Large negative or positive values indicative asymmetric or uneven gait.

Temporal gait parameters

Time taken to stand (s)

Time from 'go' to first heel strike or toe-off point.

A long time taken to stand may be indicative of lower limb weakness. Lower limb weakness (along with grip strength)⁷ is a surrogate measure of core and overall physical strength. Higher values of time to stand are associated with increased risk of falls. Targeted strength training can be used to increase lower limb strength. Overall strength can be improved by strength and balance training.

Time from last heel strike or toe-off to end of test.

Time taken to sit (s)

A long time taken to sit may be indicative of poor balance or instability. Higher values of time to sit are associated with increased risk of falls. Targeted physiotherapy can be used improve balance and lower limb strength.

Number of gait cycles

Number of gait cycles in TUG test.

Higher numbers of gait cycles are associated with increased falls risk and suggest patient is taking smaller steps.

Number of steps

Number of steps in TUG test.

Higher numbers of steps are associated with increased falls risk and suggest patient is taking smaller steps. High step count during a TUG can indicate stability of gait problems as well as overall weakness and can be addressed by targeted strength and balance training

Cadence (steps/min)	<p><i>Average number of steps taken per minute during test.</i></p> <p><i>Lower values of cadence are associated with higher falls risk and may also indicate neurological disorders. High cadence is a leading indicator of Parkinson's disease.</i></p>
Walk time (s)	<p><i>Time from first to last heel-strike or toe-off point. Length of time participant actually spends in locomotion during TUG test.</i></p> <p><i>Higher values of walk time are associated with increased falls risk. If turn parameters are normal and walk time high, patient may have walking impairment.</i></p>
Average swing time (s)	<p><i>Average swing time over all gait cycles, averaged across both legs, swing time is defined as the time between a toe-off point and the heel strike point on the same foot.</i></p>
Swing time variability (%)	<p><i>Coefficient of variation in swing time during TUG test.</i></p>
Swing time asymmetry	<p><i>Gait symmetry index for swing time: difference between right and left divided by average of right and left, expressed as a percentage.</i></p> <p><i>Longer swing times and increased (as well very low) swing time variability are associated with increased falls risk. Many measures of gait variability have been associated with increased falls risk^{8,9}. Gait variability has also been associated with cognitive decline and dementia^{10,11}. Measures of gait variability during TUG have been shown to be highly variable due to the nature of the test (and so not reliable) across multiple trials.</i></p>
Average stance time (s)	<p><i>Average stance time over all gait cycles, stance time is defined as the time between a heel-strike and toe-off point on the same foot.</i></p>
Stance time variability (%)	<p><i>Variation in stance time over TUG test.</i></p>
Stance time asymmetry	<p><i>Gait symmetry index for stance time: difference between right and left divided by average of right and left, expressed as a percentage.</i></p> <p><i>Longer stance times and increased (as well very low) stance time variability are associated with increased falls risk.</i></p>
Average stride time (s)	<p><i>Time for one stride (time between successive heel-strikes), averaged over all gait cycles.</i></p>
Stride time variability (%)	<p><i>Variation in stride time during the TUG test.</i></p>
Stride time asymmetry	<p><i>Gait symmetry index for stride time: difference between right and left divided by average of right and left, expressed as a percentage.</i></p> <p><i>Longer stride times are associated with increased falls risk. Too much or too little stride variability has been associated with increased falls risk^{6,8,12}. Measures of gait variability during TUG have been shown to be highly variable due to the nature of the test (and so not reliable) across multiple trials.</i></p>
Average step time (s)	<p><i>Average time between heel-strike on one foot to heel strike of the opposite foot, measured in seconds.</i></p>
Step time variability (%)	<p><i>Variation in step time during the TUG test.</i></p>
Step time asymmetry	<p><i>Gait symmetry index for step time: difference between right and left divided by average of right and left, expressed as a percentage.</i></p> <p><i>Longer steps times are associated with increased falls risk. Too much or too little step time variability is associated with increased falls risk⁶.</i></p>
Average double support	<p><i>Proportion of a gait cycle spent on both feet during TUG test.</i></p>
Double support variability (%)	<p><i>Variation in proportion of a gait cycle spent on both feet during TUG test.</i></p> <p><i>High values of double support are associated with increased falls risk. High double support variability can indicate highly unstable or unsure gait.</i></p>
Average single support	<p><i>Proportion of a gait cycle (time between successive steps) spent on either foot.</i></p>
Single support variability (%)	<p><i>Variation in the proportion of a gait cycle spent on a single foot.</i></p>

High values of single support are associated with increased falls risk. High single support variability can indicate unstable or unsure gait. Gait instability can be addressed through balance re-training.

Turn parameters

Pre-turn time (s)	<p>Time from 'go' to median gait event of TUG test.</p> <p>Time to the 'middle' of the TUG. Disparities between pre-turn time, turn time and post-turn time can be used to identify if patient lacks endurance (time slower in returning from turn), has trouble turning or has general gait and mobility issues.</p>
Post-turn time (s)	<p>Time from median gait event of TUG to end of test.</p> <p>Time from the 'middle' of the TUG test to return to the chair and reseat. Slower post-turn times than pre-turn times can indicate patient has trouble turning or may lack endurance.</p>
Ratio of pre-turn to post-turn times	<p>Ratio of time taken from 'go' to median gait event of TUG to the time from the median gait event during TUG, to the end of test.</p> <p>If patient is faster at walking to turn than in walking back? Lower values of this ratio indicate that patients may be struggling to turn or may lack endurance.</p>
Time taken to turn (s)	<p>Time taken to turn through 180°.</p> <p>Longer times taken to turn are strongly indicative of higher falls risk. Turning problems can also be indicator of balance or vestibular issues. Balance re-training and targeted physiotherapy improve time taken to turn. Note long times taken to turn cannot also indicate that patient has adopted a careful turn strategy with a wide base of support which is a positive strategy to maintain stability during walking and turning.</p>
Number of steps in turn	<p>Number of steps taken to turn through 180°.</p> <p>Patients taking more steps to turn than normal (see reference data below) is strongly indicative of higher falls risk. Turning problems can also be indicator of balance or vestibular issues. Balance re-training may improve patient's ability to turn along with associated stability.</p>
Turn steps/time ratio	<p>Ratio of the number of steps taken to turn to the time taken to turn.</p> <p>This is indicative of patients turn strategy. More steps taken to turn (even if time taken to turn is normal) could be considered less stable and can indicate higher falls risk.</p>

Angular velocity parameters

Forward rotation speed at turn time (deg/s)	<p>Angular velocity in sagittal plane at median event of TUG test.</p> <p>Speed patient performs turn during TUG. Slower turn speeds are associated with increased falls risk. More variable turn speed can be associated with more unsteady turning.</p>
Range of peak forward rotation speed (deg/s)	<p>Range of angular velocity in the sagittal plane at mid-swing over entire walk.</p> <p>Larger range denotes increased lower limb rotation in the forward direction. Too much or too little variation has been associated with increased falls risk.</p>
Average peak forward rotation speed (deg/s)	<p>Average angular velocity in the sagittal plane over entire walk.</p> <p>Linked to minimum ground clearance (also known as toe-clearance)^{13,14} as well as foot speed. Higher foot speed is associated with higher walking speed and reduced falls risk. Low minimum ground clearance is associated with risk of tripping¹⁴.</p>

Minimum side-to-side rotation speed (deg/s)	Minimum angular velocity in the side-to-side direction during the assessment. <i>Linked to lateral foot speed, associated with more variable and unsteady walking and higher falls risk.</i>
Maximum side-to-side rotation speed (deg/s)	Maximum angular velocity in the side-to-side direction during the assessment. <i>Linked to lateral foot speed, associated with more variable and unsteady walking and higher falls risk.</i>
Average side-to-side rotation speed (deg/s)	Average angular velocity in the side-to-side direction during the assessment. <i>Linked to lateral foot speed and increased unsteadiness in walking.</i>
Minimum forward rotation speed (deg/s)	Minimum forward angular velocity in the sagittal plane during the assessment. <i>Linked to gait velocity, has also been linked to minimum ground clearance, e.g. risk of tripping, a known falls risk. Decreased values are associated with increased falls risk.</i>
Maximum forward rotation speed (deg/s)	Maximum forward angular velocity during the assessment. <i>Linked to gait velocity, has also been linked to minimum ground clearance, e.g. risk of tripping, a known falls risk¹⁴. Decreased values are associated with increased falls risk.</i>
Average forward rotation speed (deg/s)	Average forward angular velocity during the assessment. <i>Linked to gait velocity, has also been linked to minimum ground clearance¹³, e.g. associated with risk of tripping, a known falls risk. Decreased values are associated with increased falls risk.</i>
Variation in forward rotation speed (%)	Coefficient of variation in forward angular velocity during the assessment. <i>More variable rotation of lower limbs is associated with increased falls risk. This has also been associated with increased variability in minimum ground clearance (MGC)¹⁴. Low MGC can be addressed through targeted physiotherapy and may be indicative of poor lower or hip-flexor mobility.</i>
Variation in side-to-side rotation speed (%)	Coefficient of variation in angular velocity in the side-to-side direction during the assessment. <i>Increased variation in lateral rotation of lower limbs may indicate less stability under locomotion while completing the TUG test.</i>
Minimum horizontal rotation speed (deg/s)	Minimum angular velocity in the transverse plane during the assessment. <i>Linked to minimum ground clearance (minimum distance from bottom of foot the ground during the swing phase). Low MGC is a known falls risk.</i>
Maximum horizontal rotation speed (deg/s)	Maximum angular velocity in the transverse plane during the assessment. <i>Linked to minimum ground clearance (minimum distance from bottom of foot the ground during the swing phase). Low MGC is a known falls risk.</i>
Average horizontal rotation speed (deg/s)	Average angular velocity in the transverse plane during the assessment. <i>Linked to minimum ground clearance (minimum distance from bottom of foot the ground during the swing phase). Low MGC is a known falls risk.</i>
Variation in horizontal rotation speed (%)	Coefficient of variation in angular velocity in the transverse plane during the assessment. <i>High values are associated with more variable lower limb movement.</i>

Angular velocity x Height parameters

Minimum forward rotation speed x Height *Related to average velocity of shank in forward direction.*

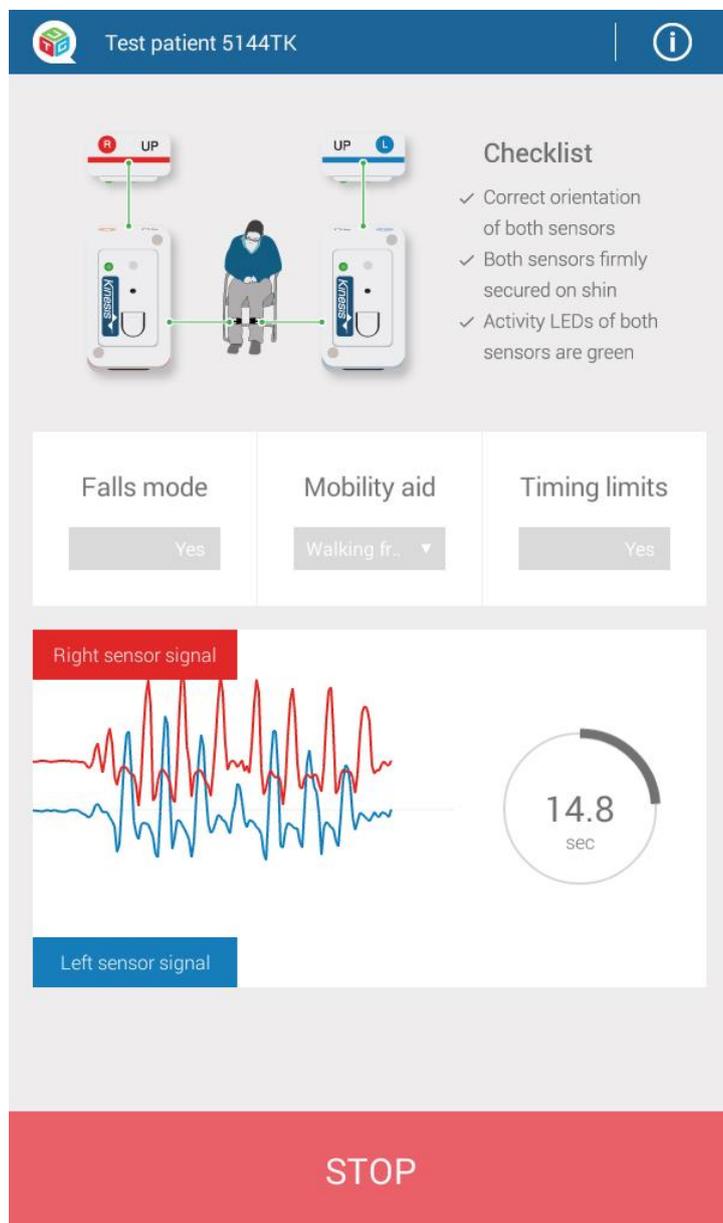
(deg.m/s)	<i>Linked to foot speed. Higher foot speed is associated with higher walking speed and reduced falls risk.</i>
Maximum forward rotation speed x Height (deg.m/s)	<i>Related to maximum linear velocity of shank in forward direction.</i> <i>Linked to foot speed. Higher foot speed is associated with higher walking speed and reduced falls risk.</i>
Average forward rotation speed x Height (deg.m/s)	<i>Related to minimum linear velocity of shank in forward direction.</i> <i>Related to lateral vertical speed, i.e. speed of foot while moving upward.</i>
Minimum side-to-side rotation speed x Height (deg.m/s)	<i>Related to minimum linear velocity of shank in side-to-side direction.</i> <i>Related to lateral foot speed.</i>
Maximum side-to-side rotation speed x Height (deg.m/s)	<i>Related to maximum linear velocity of shank in side-to-side direction</i> <i>Related to lateral foot speed.</i>
Average side-to-side rotation speed x Height (deg.m/s)	<i>Related to average linear velocity of shank in side-to-side direction</i> <i>Related to lateral foot speed.</i>
Minimum horizontal rotation speed x Height (deg.m/s)	<i>Related to minimum linear velocity of shank in vertical direction</i> <i>Related to forward foot speed.</i>
Maximum horizontal rotation speed x Height (deg.m/s)	<i>Related to maximum linear velocity of shank in vertical direction.</i>
Average horizontal rotation speed x Height (deg.m/s)	<i>Related to average linear velocity of shank in vertical direction.</i>

Further information on QTUG™ clinical research studies can be found in references^{3,15-18} and on <http://www.kinesis.ie/research/>

QTUG™ TEST RESULTS

Once a test is accepted as valid, test results are displayed and saved

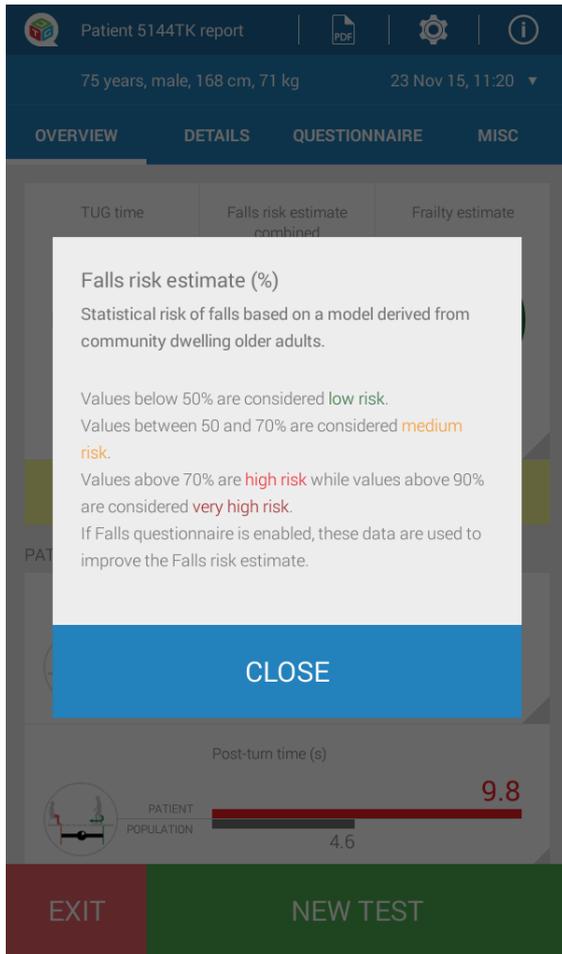
TUG TEST TIME



The **TUG test time** (also known as stopwatch TUG time) is the time taken to complete the Timed Up and Go test¹⁹.

Generally, higher values of TUG time are considered to indicate a higher falls risk. Depending on the patient population, values of 11-18s are thought to be indicative of a risk of falls²⁰. Patients exhibiting cognitive decline or dementia are also thought to have slower TUG times.

FALLS RISK ESTIMATE



The **Falls Risk Estimate (FRE)** is a statistical estimate of a patient's risk of having a fall. Statistics are based on a large reference population of community dwelling older adults.

FRE scores below 50% are considered **low risk**. FRE scores in the range 50% to 69% are considered **medium risk**, while scores above 70% are considered **high risk**, with scores about 90% considered **very high risk**.

QTUG Falls risk estimate scores

■	Low risk	0% to <50%
■	Medium risk	50% to <70%
■	High risk	70% to <90%
■	Very high risk	90% to 100%

QTUG™ also contains a questionnaire on patient's falls risk factors, based on the AGS/BGS falls questionnaire. **If falls risk questionnaire is enabled, these data are used to improve the FRE.**

Three FRE values are produced is the questionnaire is completed and software is in **Falls mode**:

QTUG FRE

- Sensor FRE** The falls risk estimate calculated using sensor data and demographic data
- Clinical FRE** Falls risk estimate calculated from the clinical data entered through the falls questionnaire along with demographic data.
- Combined FRE** Weighted average of the sensor and clinical FRE values

A suggested care pathway for integrating QTUG™ into Falls prevention programmes is provided (see Falls Care Pathway section). This falls prevention care pathway ranges from education and recommended exercise programmes for patients considered at **low risk** of falls to one-on-one assessment, tailored physiotherapy programmes as well as home/personal monitoring for patients deemed at **high risk** and **very high risk**. Patients deemed at **medium risk** receive falls prevention education as well as group exercise classes (exercise interventions have been proven to reduce incidences falls by 30%-40%²¹) and personal emergency response (PERS) monitoring.

In assessment of patients, the FRE score should be used in conjunction with evaluation of the patient's mobility scores. The mobility scores may highlight what aspect of a patient's mobility may benefit from targeted therapy.

FRAILITY ESTIMATE



The **Frailty Estimate (FE)** is a statistical estimate of a patient's risk of having a fall. Statistics are based on a large reference population of community dwelling older adults.

Frailty scores below 50% are considered **non-frail**. FRE scores in the range 50-69% are considered **transitional**, while scores above 70% are considered **frail**, with scores about 90% considered **very frail**.

QTUG Frailty scores

Green	Non-frail	0% to <50%
Yellow	Transitional	50% to <70%
Red	Frail	70% to <90%
Dark Red	Very frail	90% to 100%

A suggested care pathway for integrating QTUG™ into Falls prevention programmes is provided (see Falls Care Pathway section). This falls prevention care pathway ranges can also be applied to patients Frailty state as measured by QTUG™.

QTUG™ also contains a questionnaire on patient's falls risk factors, based on the AGS/BGS falls questionnaire. **If falls risk questionnaire is enabled, these data are used to improve the FE.**

In assessment of patients, the Frailty estimate should be used in conjunction with the FRE score the patient's comparison against reference data. Comparison to reference data may highlight what aspect of a patient's mobility may benefit from targeted therapy.

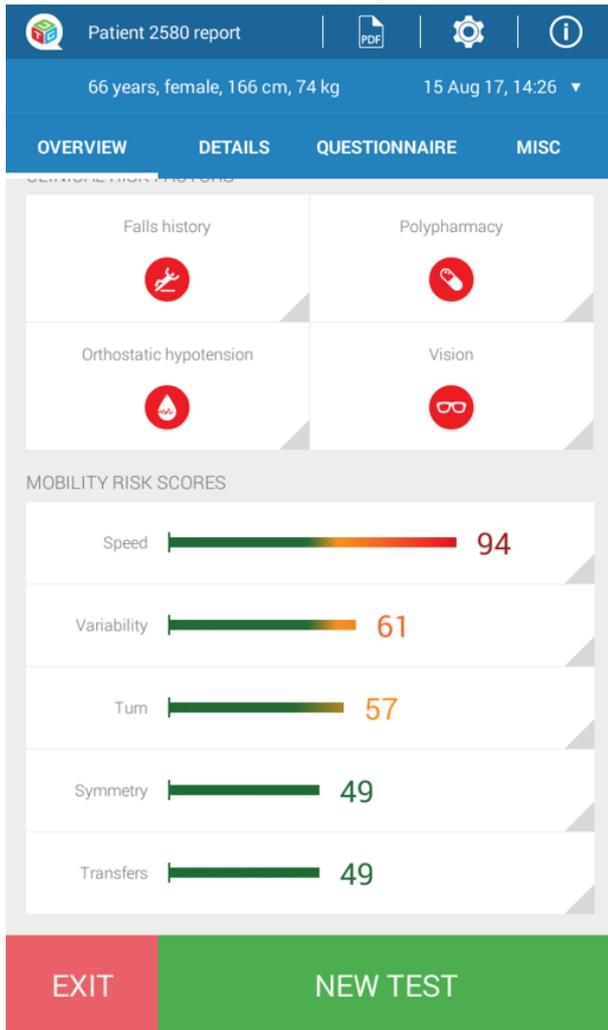
Three FE values are produced is the questionnaire is completed and software is in **Falls mode**:

QTUG FE

- Sensor FE** The frailty estimate calculated using sensor data and demographic data based on a model derived from Fried's frailty phenotype.
- Clinical FE** Frailty estimate calculated from the clinical data entered through the falls questionnaire along with demographic data.
- Combined FE** Weighted average of the sensor and clinical FE values

In assessment of patients, the FE score should be used in conjunction with evaluation of the patient's FRE and mobility scores. The mobility scores may highlight what aspect of a patient's mobility may benefit from targeted therapy.

MOBILITY RISK SCORES



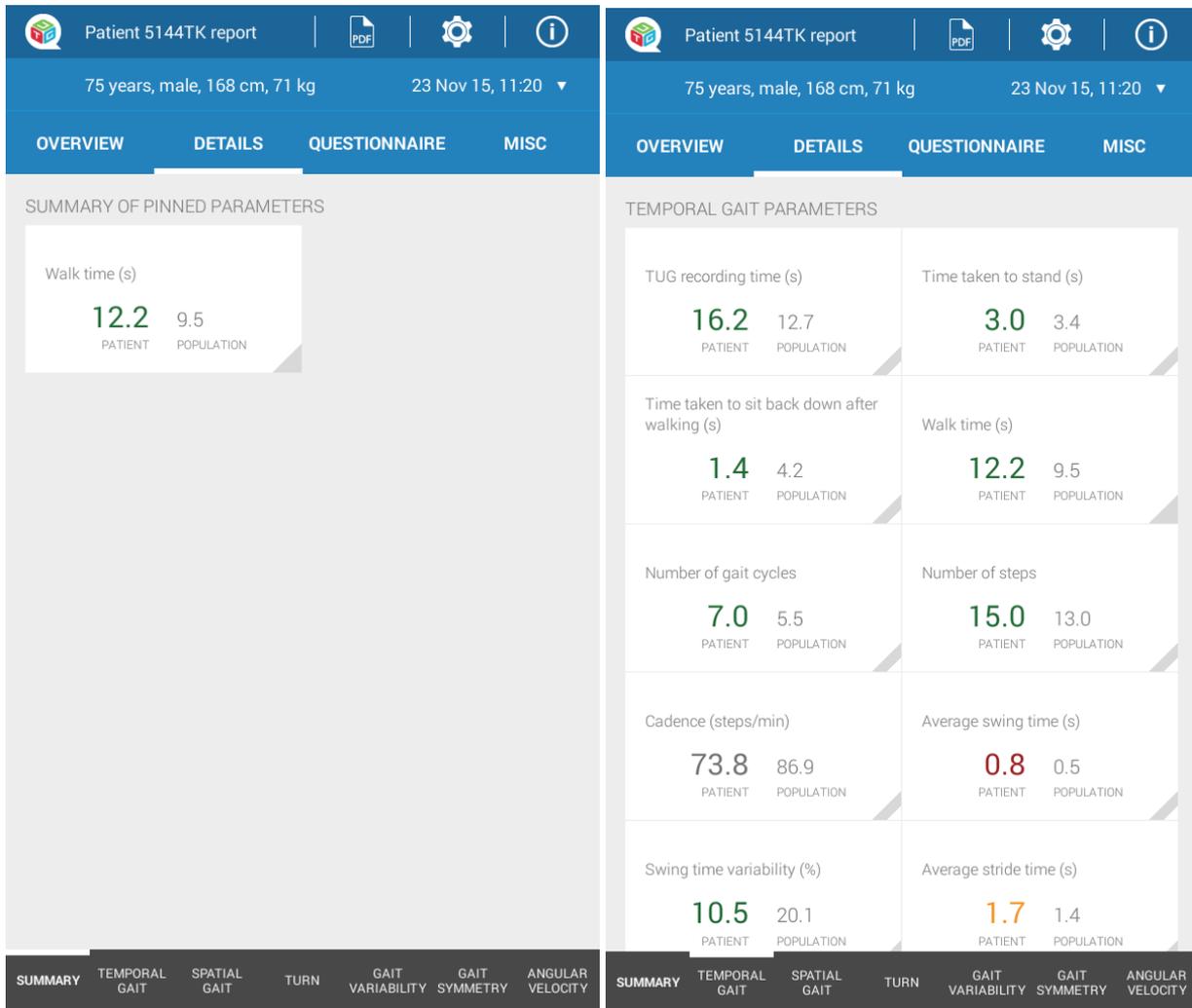
Each QTUG assessment can be broken down into five functional areas:

- **Speed** – assessment of parameters relating to walking speed.
- **Variability** – assessment of gait variability. A high variability score indicates high gait variability which is linked to risk falls.
- **Symmetry** – assessment of gait asymmetry. A high symmetry score indicates gait asymmetry during the TUG test. Gait asymmetry is associated with neurological disorders.
- **Transfers** – assessment of sit to stand and stand to sit transfers. A high transfer score indicates difficulty in standing or sitting, which has been linked to poor lower limb and core strength.
- **Turning** – assessment of patient’s ability to turn. A high turn score indicates problems with turning which is linked to balance impairment and falls risk.

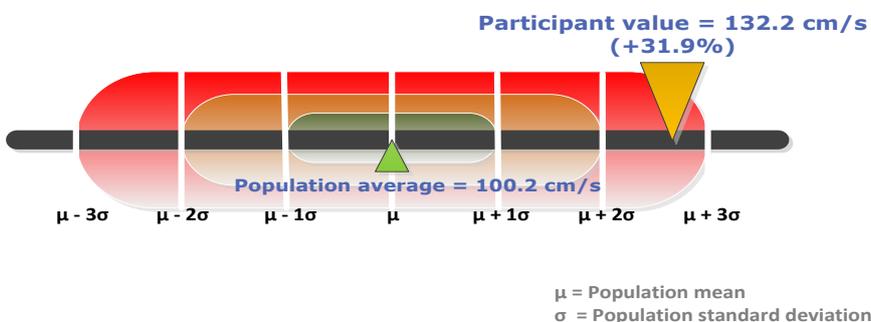
Each mobility score is calculated by comparing the patient’s mobility against population data for their age and gender. The mobility score is a percentile with high scores indicating higher levels of impairment. A mobility score of less than 50% is considered highlighted in **Green** and considered within the normal range, while mobility scores 50-69%, highlighted in **Amber** may indicate a parameter is unusual compared to the population average. Mobility scores highlighted in **Red** are outside the normal range and may indicate a specific mobility impairment. For example if a patient’s turn score is red, this indicate the patient has problems turning, may have a balance impairment and could benefit from specific balance retraining exercises.

COMPARISON TO REFERENCE DATASET*

Each inertial sensor parameter for a given patient is compared to an average value for their age and gender (derived from a reference population). Values outside normal range may indicate mobility impairment or very high performance.



Note: The image above displays a sample set of parameters from the full mobility assessment provided by QTUG™, where the user has customise which parameters to display.



*Values provided in this document are stratified by gender. However, results provided by QTUG™ may differ slightly, as data are stratified by age category as well as gender.

QTUG™ parameter values that are significantly different compared to the reference population and may indicate a specific mobility impairment are highlighted in **Red** (e.g. TUG time value of 20.9s compared to population average of 10.8s). Parameters highlighted in **Green** are considered within the normal range, while **Amber** may indicate a parameter is unusual compared to the population average.



**Values provided in this document are stratified by gender. However, results provided by QTUG™ may differ slightly, as data are stratified by age category as well as gender.*

The QTUG software contains a reference data set, derived from 9 years of research (www.kinesishhealthtech.com/research), containing data from **1495 participants** (981 female, 514 male), mean age 71.3±12.5, mean weight 73.3±14.9kg and mean height 165.4±9.8 cm. The data consist of QTUG data obtained from community dwelling older adults, healthy young controls participants as well as participants with multiple sclerosis (MS) and Parkinson’s disease (PD) between 2008 and 2017.

The average population values for each gender and range are detailed in the Table below.

Parameter	Gender	Average	Normal range	Unusual	Warning
Temporal gait parameters					
TUG recording time (s)	M	10.58	(6.69-14.21)	>17.85	>21.49
	F	10.95	(6.69-15.21)	>19.47	>23.73
Walk time (s)	M	7.84	(4.95-10.59)	>13.35	>16.10
	F	8.21	(4.95-11.46)	<1.70 >14.71	>17.96
Average double support	M	0.21	(0.13-0.28)	<0.06 >0.36	>0.43
	F	0.22	(0.13-0.30)	<0.05 >0.39	>0.47
Double support variability (%)	M	46.24	(23.73-67.77)	<3.16 >89.31	>110.85
	F	46.26	(23.73-68.79)	<1.20 >91.33	>113.86
Number of gait cycles	M	4.75	(3.75-6.25)	>7.75	>9.26
	F	5.34	(3.75-6.93)	>8.52	>10.11
Average single support	M	0.38	(0.32-0.43)	>0.49	>0.54
	F	0.37	(0.32-0.43)	>0.48	>0.54
Single support variability (%)	M	18.99	(8.67-27.80)	<1.37 >36.61	>45.42
	F	17.83	(8.67-27.00)	>36.16	>45.32
Average stance time (s)	M	0.78	(0.56-0.96)	>1.13	>1.31
	F	0.74	(0.56-0.92)	>1.10	>1.27
Stance time variability (%)	M	41.35	(22.74-58.67)	<6.71	>93.32

	F	41.41	(22.74-60.08)	>75.99 <4.07	>97.42
				>78.75	
Stance time asymmetry	M	2.09	(-21.65-25.88)	<-45.50	<-69.29
	F			>49.68	73.47
				<-46.82	<-71.98
	F	3.51	(-21.65-28.67)	>53.83	79.00
Average step time (s)	M	0.63	(0.47-0.75)	>0.87	>1.00
	F	0.58	(0.47-0.70)	>0.82	>0.93
Step time variability (%)	M	26.90	(5.56-44.01)	>61.13	>78.24
	F	25.43	(5.56-45.31)	>65.18	>85.05
Step time asymmetry (%)	M	-1.62	(-28.490-22.80)	<-50.45	<-74.87
				>47.21	>71.63
	F			<-53.62	<-78.74
	F	-3.37	(-28.49-21.76)	>46.88	>72.01
Number of steps	M	11.59	(9.59-14.37)	>17.15	>19.94
	F	12.70	(9.59-15.80)	>18.91	>22.02
Average stride time (s)	M	1.34	(1.03-1.57)	>1.80	>2.04
	F	1.25	(1.03-1.46)	>1.68	>1.89
Stride time variability (%)	M	28.64	(16.96-40.50)	<4.90	>64.24
				>52.37	
	F	29.18	(16.96-41.40)	>4.74	>65.84
				>53.62	
Stride time asymmetry	M	0.96	(-15.32-18.13)	<-33.37	<-50.53
				>35.29	>52.46
	F	2.37	(-15.32-20.05)	<-33.00	<-50.69
				>37.74	>55.42
Cadence (steps/min)	M	92.53	(81.33-107.76)	<62.07	<46.84
				>122.99	
	F	97.41	(81.33-113.48)	<65.26	<49.19
				>129.55	
Average swing time (s)	M	0.51	(0.39-0.58)	>0.66	>0.74
	F	0.46	(0.39-0.53)	>0.60	>0.67
Swing time variability (%)	M	20.35	(5.70-34.20)	>48.06	>61.91
	F	19.12	(5.70-32.55)	>45.97	>59.40
Swing time asymmetry	M	0.92	(-14.77-15.73)	<-28.69	<-43.49
				>30.53	>45.33
	F	0.77	(-14.77-16.31)	<-30.31	<-45.85
				>31.85	>47.42
Time taken to stand (s)	M	2.90	(1.40-4.26)	>5.61	>6.96
	F	2.87	(1.40-4.34)	>5.81	>7.27

Time taken to sit (s)	M	3.90	(1.47-6.20)	>8.50	>10.79
	F	4.09	(1.47-6.70)	>9.32	>11.93
Spatial gait parameters					
Average stride velocity (cm/s)	M	101.58	(72.63-129.61)	<45.51	<17.47
	F	101.06	(72.63-129.50)	<44.19	<15.75
Stride velocity variability (%)	M	35.25	(18.62-48.97)	<7.81 >62.69	>76.41
	F	34.37	(18.62-50.12)	<2.87 >65.87	>81.62
Average stride length (cm)	M	130.82	(94.51-158.54)	<75.38	<47.66
	F	122.19	(94.51-149.88)	<66.83	<39.15
Stride length variability (%)	M	18.32	(1.70-32.19)	>46.06	>59.93
	F	18.73	(1.70-35.76)	>52.80	>69.83
Turn parameters					
Number of steps in turn	M	1.71	(0.99-2.54)	>3.37	>4.20
	F	1.94	(0.99-2.89)	>3.84	>4.79
Time taken to turn (s)	M	3.04	(1.58-4.23)	>5.43	>6.63
	F	3.08	(1.58-4.59)	>6.09	>7.60
Turn steps/time ratio	M	0.61	(0.34-0.92)	>1.23	>1.54
	F	0.70	(0.34-1.06)	>1.42	>1.78
Post-turn time (s)	M	4.11	(2.25-5.64)	>7.17	>8.70
	F	4.30	(2.25-6.340)	>8.38	>10.42
Pre-turn time (s)	M	3.73	(2.38-5.06)	>6.40	>7.73
	F	3.95	(2.38-5.52)	>7.10	>8.67
Ratio of pre-turn to post-turn times	M	1.12	(0.81-1.32)	<0.72 >1.51	<0.53 >1.71
	F	1.11	(0.81-1.41)	<0.51 >1.71	>2.01
Angular velocity parameters					
Average peak forward rotation speed (deg/s)	M	109.42	(89.62-133.24)	<61.78 >157.06	<37.96 >180.88
	F	116.98	(89.62-144.33)	<62.27 171.68	<34.92 >199.04
Range of peak forward rotation speed (deg/s)	M	90.96	(64.38-114.14)	<44.61 >137.32	<21.43 >160.50
	F	91.75	(64.38-119.11)	<37.02 >146.47	<9.65 >173.84

Variation in side-to-side rotation speed (%)	M	141.07	(117.54-167.46)	<88.28 193.86	<61.89 >220.25
	F	143.15	(117.54-168.77)	<91.92 194.38	<66.31 220.00
Maximum side-to-side rotation speed (deg/s)	M	167.33	(124.60-217.14)	<67.71 >266.96	<17.89 >316.77
	F	183.82	(124.60-243.04)	<65.38 >302.26	<6.16 >361.49
Maximum side-to-side rotation speed x Height (deg.m/s)	M	291.94	(199.47-382.84)	<110.15 >473.74	<19.25 >564.64
	F	296.18	(199.47-392.90)	<102.75 >489.62	<6.03 >586.33
Average side-to-side rotation speed (deg/s)	M	18.55	(12.24-24.91)	<5.84 >31.26	>37.62
	F	19.50	(12.24-26.76)	<4.98 >34.03	<-2.29 >41.29
Average side-to-side rotation speed x Height (deg.m/s)	M	32.30	(19.80-43.55)	<9.80 >54.79	<-1.45 >66.04
	F	31.37	(19.80-42.95)	<8.22 >54.53	<-3.36 >66.11
Minimum side-to-side rotation speed (deg/s)	M	-171.03	(-235.87-119.05)	<-275.00 >-67.07	<-326.98 >-15.09
	F	-182.14	(-235.87-128.41)	<-289.61 >-74.68	<-343.34 >-20.95
Minimum side-to-side rotation speed x Height (deg.m/s)	M	-298.12	(-380.39-204.63)	<-485.12 >-111.13	<-578.62 >-17.63
	F	-293.41	(-380.39-206.42)	<-467.38 >-119.44	<-554.37 >-32.45
Variation in forward rotation speed (%)	M	133.18	(110.08-158.10)	<83.34 183.02	<58.42 >207.94
	F	134.14	(110.08-158.20)	<86.02 >182.27	<61.96 >206.33
Maximum forward rotation speed (deg/s)	M	145.20	(120.67-172.95)	<89.68 >200.71	<61.93 >228.47
	F	152.71	(120.67-184.75)	<88.62 >216.79	<56.58 >248.83
Maximum forward rotation speed x Height (deg.m/s)	M	252.82	(194.00-303.13)	<152.19 >353.45	<101.87 >403.76
	F	245.76	(194.00-297.53)	<142.24 >349.29	<90.48 >401.05
Average forward rotation speed (deg/s)	M	22.88	(15.01-30.69)	<7.27 >38.49	<-0.53 >46.30
	F	23.82	(15.01-32.63)	<6.19 >41.44	<-2.62 >50.25
Average forward rotation speed x Height	M	39.81	(24.42-53.54)	<12.35	<-1.38

(deg.m/s)			>67.26	>80.99
	F	38.24	(24.42-52.07)	<10.59
			>65.89	>79.72
Minimum forward rotation speed (deg/s)	M	-91.14	(-117.60--71.57)	<-130.27
	F	-93.57	(-117.60--69.55)	<-141.62
			>-52.01	>-32.44
Minimum forward rotation speed x Height (deg.m/s)	M	-158.66	(-188.92--123.59)	<-228.79
	F	-150.53	(-188.92--112.15)	<-227.30
			>-88.53	>-53.46
			<-73.77	>-35.39
Forward rotation speed at turn time (deg/s)	M	18.40	(-15.89-51.88)	<-48.56
	F	20.31	(-15.89-56.50)	<-52.08
			>85.37	>118.85
			>92.70	>128.89
Variation in horizontal rotation speed (%)	M	136.77	(116.60-161.49)	<87.34
	F	141.56	(116.60-166.52)	<91.63
			>186.21	>210.93
			>191.49	>216.45
Maximum horizontal rotation speed (deg/s)	M	91.53	(62.61-121.37)	<31.87
	F	90.42	(62.61-118.24)	<34.80
			>151.20	>181.03
			>146.05	>173.87
Maximum horizontal rotation speed x Height (deg.m/s)	M	159.34	(100.02-212.11)	<53.82
	F	145.72	(100.02-191.42)	<54.32
			>264.87	>317.63
			>237.13	>282.83
Average horizontal rotation speed (deg/s)	M	12.13	(6.61-17.15)	<2.10
	F	10.54	(6.61-14.47)	<2.68
			>22.17	>27.18
			>18.39	>22.32
Average horizontal rotation speed x Height (deg.m/s)	M	21.08	(10.64-29.68)	3.86
	F	16.96	(10.64-23.28)	<4.32
			<38.29	>46.89
			>29.60	>35.93
Minimum horizontal rotation speed (deg/s)	M	-83.12	(-107.14--51.55)	<-146.26
	F	-76.13	(-107.14--45.12)	<-138.14
			>-19.99	>11.58
			>-14.12	>16.89
Minimum horizontal rotation speed x Height (deg.m/s)	M	-144.70	(-173.37--89.34)	<-255.40
			>-33.99	>21.37
		-122.79	(-173.37--72.20)	<-223.96
			>-21.61	>28.97

FALLS QUESTIONNAIRE

Patient 5144TK

FALLS QUESTIONNAIRE

Have you fallen in the last 12 months? No Yes

How many times?

Have you had any problems walking or moving around? No Yes

Are you taking four or more prescription medications? No Yes

Do you have any problems with your feet? No Yes

Have you had any problems with your blood pressure dropping when you stand up? No Yes

Do you feel dizzy when you stand up from a sitting position? No Yes

Do you have any problems with your vision? No Yes

The falls questionnaire is an optional setting in QTUG™. The questionnaire is based on the American Geriatric Society (AGS) and British Geriatric Society (BGS) guidelines for assessing risk of falls²².

Falls risks identified through the QTUG™ falls questionnaire should be used in conjunction with the data provided by QTUG™ to assess a patient's risk of falls and appropriate treatment (if any). **If falls risk questionnaire is enabled, these data are used to improve the falls risk and frailty estimates.**

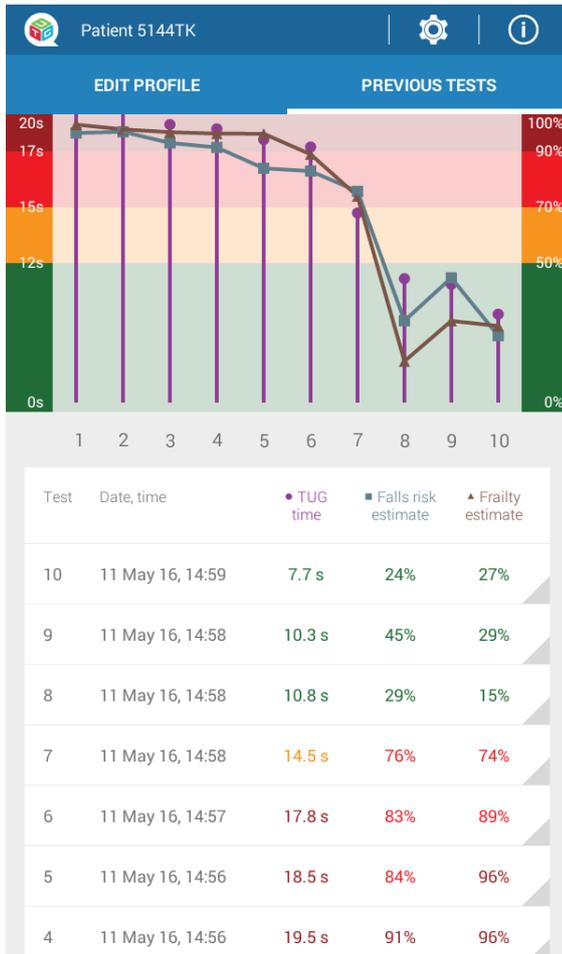
Known falls risks such as polypharmacy (four or more prescribed medications) and vision problems (in particular poor contrast sensitivity)²³⁻²⁶, are independent of falls risks arising from mobility impairment.

Significantly, gait and mobility are **modifiable falls risks** and can be reduced through targeted intervention. It has been shown that incidence of falls can be reduced by **30-50%** through such intervention, which often consists of physiotherapy programmes targeted to a patient's known physical weaknesses^{21,27}.

QTUG™ falls questionnaire

- 1 Have you fallen in the last 12 months? Y/N, if Y: How many times?
- 2 Have you had any problems walking or moving around? Y/N
- 3 Are you taking 4 or more medications? Y/N
- 4 Do you have any problems with your feet? Y/N
- 5 Have you had any problems with your blood pressure dropping when you stand up? Y/N
- 6 Do you feel dizzy when you stand up from a sitting position? Y/N
- 7 Do you have any problems with your vision? Y/N
- 8 Have you had any change in your ability to manage your routine activities in the home? Y/N

HISTORICAL TRENDS



Data obtained from periodic QTUG™ assessments can be trended over time. Examination of changes in specific mobility parameters, FRE or FE can be used to determine how well a patient is responding to therapy. Change in certain parameters (e.g. increase in turning time or TUG time, decrease in gait velocity) may be indicative of increased falls risk.

ADVICE BASED ON QTUG ASSESSMENT

The screenshot displays a patient report for 'Patient 5144TK report' on '16 Apr 15, 11:34'. The patient's details are '86 years, male, 164 cm, 78 kg'. The interface has tabs for 'OVERVIEW', 'ADVICE', 'DETAILS', and 'MISC'. The 'ADVICE' tab is active, showing a section for 'CLINICAL RISK FACTORS' with four items:

- Falls history:** Patient reported two falls in the past year. A history of falls is a very strong risk factor for future falls.
- Polypharmacy:** Patient reported using four or more prescription medications which is a major risk factor for falls. A medication review may be warranted.
- Vision:** Patient reported vision problems which can be linked to falls. Check if current eyewear prescription is up to date. Referral to optician may be required.
- Orthostatic hypotension:** Patient reported orthostatic hypotension (dizziness when standing up), this can be strongly linked to falls. Referral to GP if issue has not yet been addressed.

Below this is a 'MOBILITY ASSESSMENT' section with one item:

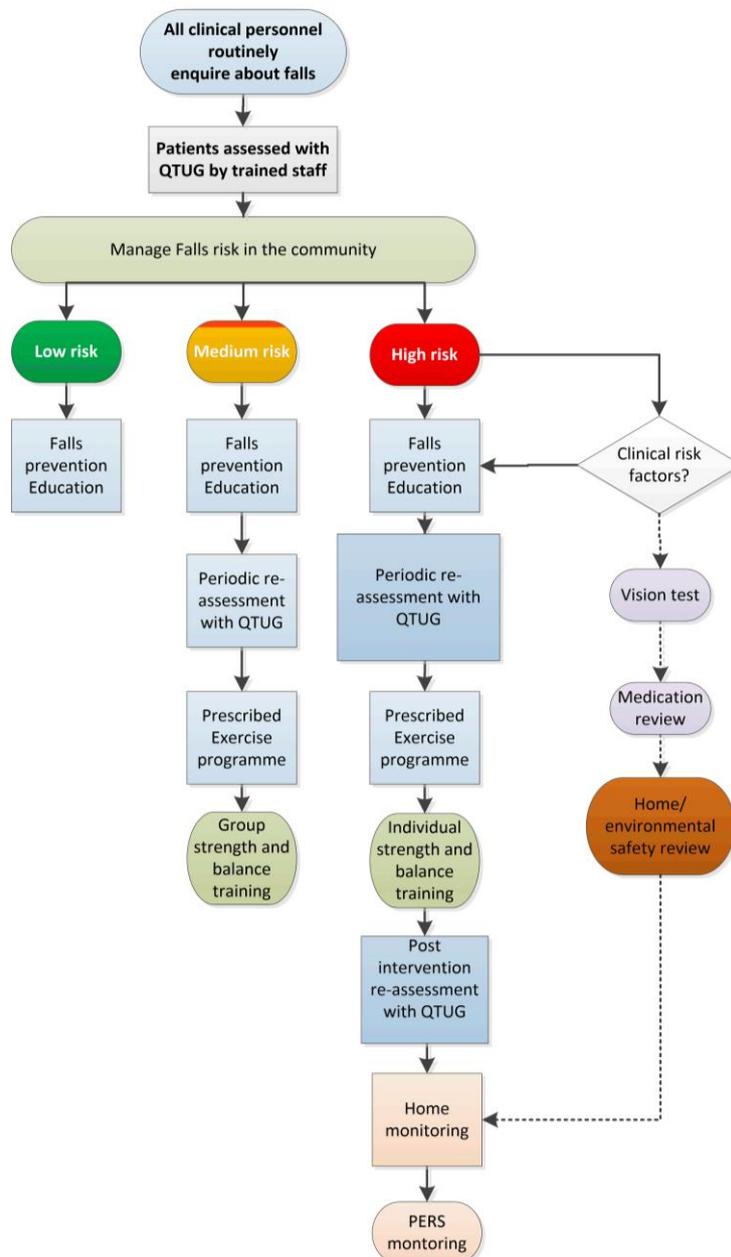
- Variability:**

Clinical fall risk factors identified through the QTUG™ falls questionnaire are highlighted in the results. Advice is provided on serious falls risk factors such as polypharmacy (four or more prescribed medications) and vision problems (in particular poor contrast sensitivity)²³⁻²⁶.

QTUG™ will provide advice based on the clinical risk factors and mobility risk scores reported. If a patient reports. Is found to have a clinical risk factor (e.g. polypharmacy, taking four or more prescription medications) this will be highlighted in the results screen. The advice screen will provide recommended advice, based on best practice.

FALLS CARE PATHWAY

Suggested care pathway for falls prevention using QTUG™



GLOSSARY

Glossary of terms used to define QTUG™ parameters

Term	Definition
Heel strike	Time of initial contact (IC) of foot with ground
Toe off	Time of terminal contact (TC) of foot with ground
Gait cycle	Movement of both legs in the time between one heel strike to the next heel strike on the same foot
Gait event	Heel strike, toe-off or mid-swing times
Gait cycle	Time from one gait event to the next gait event of the same foot
Stride time	Time from one heel strike to the next heel strike of the same foot
Stride length	Distance travelled during a stride
Step time	Time from one heel strike to the next heel strike of the opposite foot
Step length	Distance travelled during a step
Single support	Proportion of gait cycle time spent on one foot
Double support	Proportion of gait cycle time spent on two feet
Swing time	Time during a stride when foot is not on the ground
Stance time	Time during a stride when foot is on the ground
Cadence	Number of steps taken per minute
Variability/Variation	Variation in QTUG™ mobility parameters is measured using coefficient of variation (%)
Range	Difference between maximum and minimum
Rotation speed	Angular velocity (deg/s)
Side-to-side rotation	Coronal angular velocity
Horizontal rotation	transverse angular velocity
Forward rotation	sagittal angular velocity
Technical name	Variable name used in scientific publications
Parameter definition	Variable name used for derived parameters in QTUG™ software interface and user instruction
Description	Detailed description of each inertial sensor for user instruction
Population mean	Average value of a given QTUG™ parameter for the population (calculated from large reference data set)
Participant value	Value of a given QTUG™ parameter for the patient under test
Comparison to ref. data	QTUG™ parameter value for a given patient is deemed outside the normal range for patient's age and gender if it is greater than two standard deviations away from the population mean
Minimum ground clearance	Minimum distance from the sole of the foot to the ground during the swing phase of gait. Low minimum ground clearance (MGC) is a known falls risk ^{13,14} .

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