QTUG™

HOSPITAL CASE STUDY: ST VINCENTS' HOSPITAL, MEDICINE FOR THE ELDERLY (MEDEL)

VERSION 1.0

Executive summary

95 patients were assessing using the Kinesis QTUG™ mobility and falls risk assessment tool at the St Vincent's hospital, Medicine for Elderly (MedEl) clinic, Dublin 4, Ireland.

98 recordings were obtained from 95 community dwelling older adults (42 M, 56 F), QTUG™ was used to assess each patient's risk of falls as well as to identify any mobility or gait impairments (as compared to average values for patient's age and gender).

Summary results for the patient cohort are provided as well as individual patient case studies. Individual case studies highlight patients with falls risk not currently identified by current methods as well as patients with specific mobility impairment that might suggest a propensity to fall.

About Kinesis

Founded in 2013, **Kinesis Health Technologies** is an award-winning Irish health technology start-up company. Kinesis are a spin-out of University College Dublin and a large ageing research centre, the Technology Research for Independent Living (TRIL) Centre. Our proprietary technology has been validated as part of an extensive programme of top-tier internationally peer-reviewed research in Falls Prevention over the past eight years.

Kinesis QTUG™, a patent protected Mobility and Falls Risk Assessment technology, is based on the Timed Up and Go (TUG) test. Patients are instrumented with body-worn sensors to provide a quantitative assessment of mobility. The technology provides an objective assessment of mobility, a statistical estimate of falls risk and frailty as well as identification of mobility impairment by comparison against a large reference population of older adults.

QTUG™ is a Class I medical device in the EU, US and Canada. It is intended for use by a range of healthcare professionals assessing or managing falls in older people across primary, secondary and residential care. www.kinesis.ie.

Contents

Introduction

Falls are the most common cause of injury and hospitalization and one of the principal causes of death and disability in older adults worldwide[15, 17, 26]. Accurate identification of patients at risk of falls could lead to timely medical intervention, reducing the incidence of falls related injuries along with associated costs[20].

Frailty in older adults has emerged as an important geriatric syndrome which is strongly associated with falls [4, 13, 16]. Frailty is a multi-factorial condition, influenced by the combination of physical, psychological and social health. It has been shown that frailty has statistically significant predictive associations with five important health outcomes: death, first hospitalization, first fall, worsening activities of daily living (ADL) disability and worsening mobility [4, 18]. Owing to the multi-factorial nature of falls and frailty, an objective method to reliably identify patients at risk of falls or frailty could be used to target interventions which may prevent falls or a descent into frailty. Periodic assessments would enable objective monitoring over time.

Gait and mobility and one of the most prevalent falls risk factors[5]. Crucially gait and mobility are **modifiable** risk factors in that they can respond to appropriate therapy. Studies have shown that falls prevention and intervention programmes can reduce the incidence of falls by 30-40% [5, 6]. Currently there is no fast, reliable and accurate method to assess risk of falls and frailty.

Kinesis QTUG™ can identify patients at risk of falls and frailty as well as identifying gait and mobility impairments.

Data

95 older adults (54 female, 41 male), were assessed at the St Vincent's hospital Medicine for the Elderly clinic (Dublin, 4, Ireland). Participants were community dwelling older adults, aged 68-98 (mean age: 81.2±8.9, mean weight: 69.1±17.0, mean height: 164.0±10.2) and referred into the hospital. Test subjects below the target age group were excluded from analysis.

45 patients reported a history of falls, 76 patients had polypharmacy (use of four or more prescription medications), while 35 reported vision problems.

Each patient was assessed using Kinesis QTUG™ while completing a Timed Up and Go (TUG) test (see Figure 1 below).
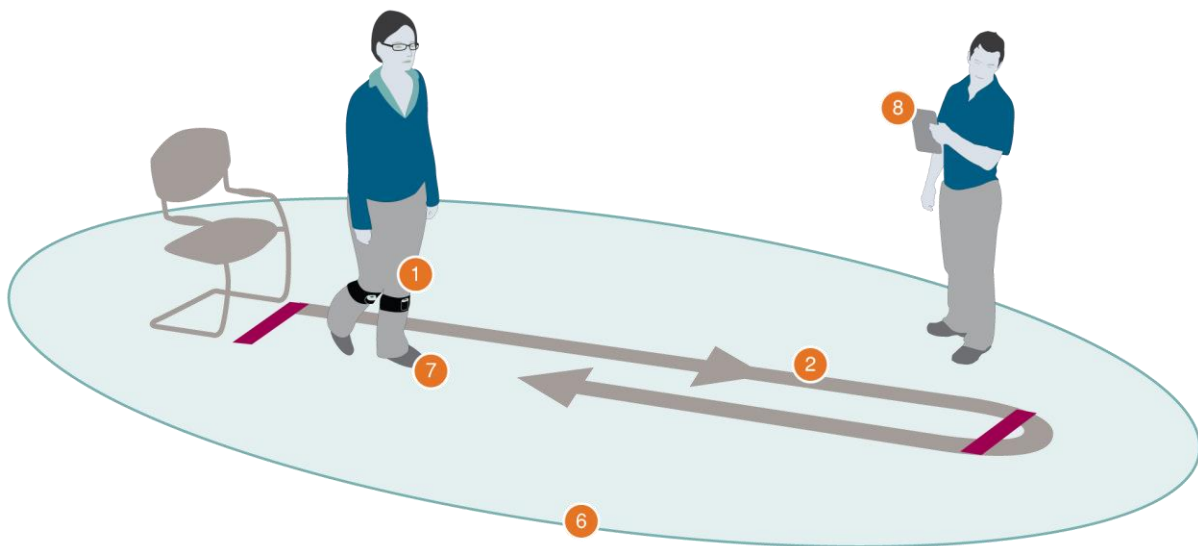

Figure 1: The TUG test quantified using QTUG.

Each patient wore a wireless inertial sensor on each shin (1), and were asked to stand-up from a chair, walk three metres (2), turn through 180° and return to the chair, as fast as safely possible. Data were streamed wirelessly to a tablet device for real-time analysis (8).

Patients were asked to complete the AGS/BGS Falls history questionnaire detailed in Table 1.

#	Question
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?
3	Are you taking 4 or more prescription medications?
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?
6	Do you feel dizzy when you stand up from a sitting position?
7	Do you have any problems with your vision?
8	Have you had any change in your ability to manage your routine activities in the home?

Table 1: QTUG™ Falls Questionnaire based on AGS/BGS falls questionnaire.

QTUG™ results

The mean TUG time for the 95 participants was 17.49±9.77s (range: 7.22-45.60s). Figure 2 below illustrates a histogram of the recorded population, 53 of 95 patients had a TUG time of 15s or below.
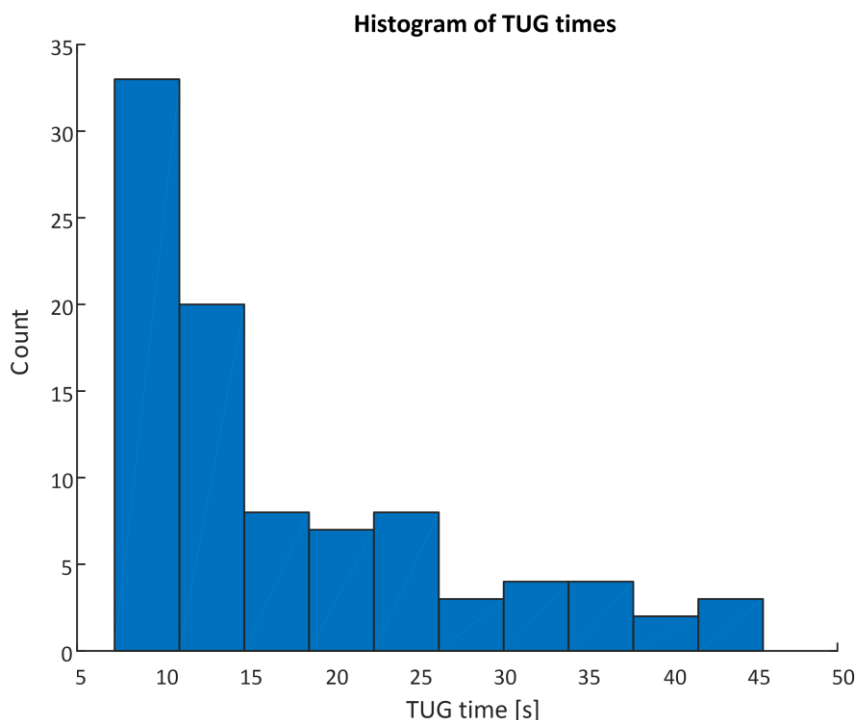

Figure 2: Histogram of TUG times.

Falls risk estimate

QTUG combines sensor and clinical risk factor data to produce a statistical estimate of falls risk, known as the Falls Risk Estimate (FRE). Individual estimates based entirely on sensors data and demographic data or clinical risk factors are provided as well as a combined estimate of falls risk. Figure 3 details how falls risk estimate (FRE) scores produced by QTUG™ should be interpreted[8-10].

QTUG™ Falls risk estimate scores

Low risk   0% to <50%

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🟧	Medium risk	50% to <70%
🟥	High risk	70% to <90%
🟥	Very high risk	90% to 100%

Figure 3: Interpretation of falls risk estimate scores

The mean Falls risk estimate for the population was 63.32%, which is considered **Medium** risk and more at risk of falls than the QTUG™ reference population of community dwelling older adults.

A suggested falls prevention care pathway based on this interpretation is provided in section "*QTUG™ falls care pathway*" below. Further information can be found in the Kinesis QTUG™ results interpretation and guidance document.

Frailty estimate

QTUG™ uses sensor and demographic data to produce a statistical estimate of frailty, based on the phenotype of frailty defined by Fried[4, 9], known as the Frailty score. Figure 4 details how frailty scores produced by QTUG™ for each patient should be interpreted.

QTUG™ Frailty scores

🟩	Non-frail	0% to <50%
🟨	Transitional	50% to <70%
🟥	Frail	70% to <90%
🟥	Very frail	90% to 100%

Figure 4: Interpretation of frailty score.

The mean Frailty score for the population was 70.76% which is considered **Frail** and suggests the population under study were deemed markedly more frail than the QTUG reference population of community dwelling older adults.

Results for the QTUG falls risk and Frailty assessments for each participant are detailed in Appendix II (Table 7).

Figure 5 below details the average TUG time per falls risk and frailty risk category. As expected, TUG time increases with increasing risk however in the lower risk categories a faster TUG test does not necessarily imply a low risk of falls and frailty.
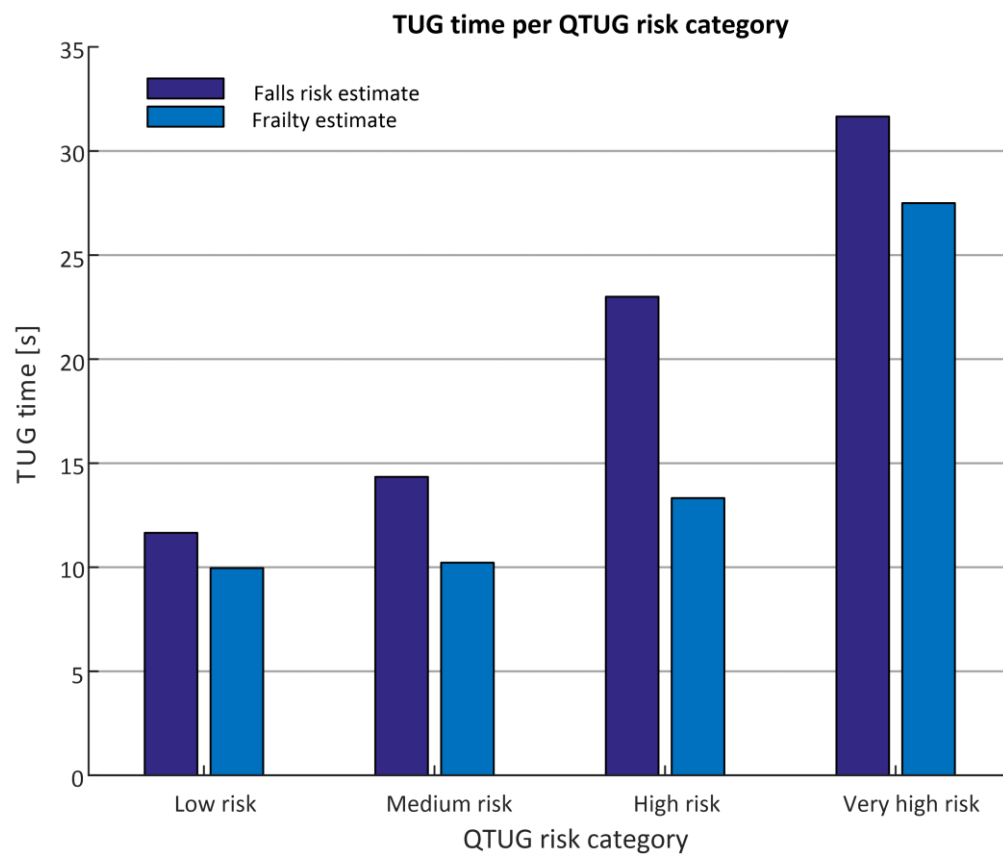
Figure 5: Mean TUG time per falls risk and frailty category. Risk categories are determined by QTUG™.

Figure 6 below illustrates how the falls risk and frailty scores relate to each other on this cohort, while generally, patients considered at **very high risk** of falls are also considered **very frail** there are certain patients considered **frail** who are considered at **medium risk** of falling.
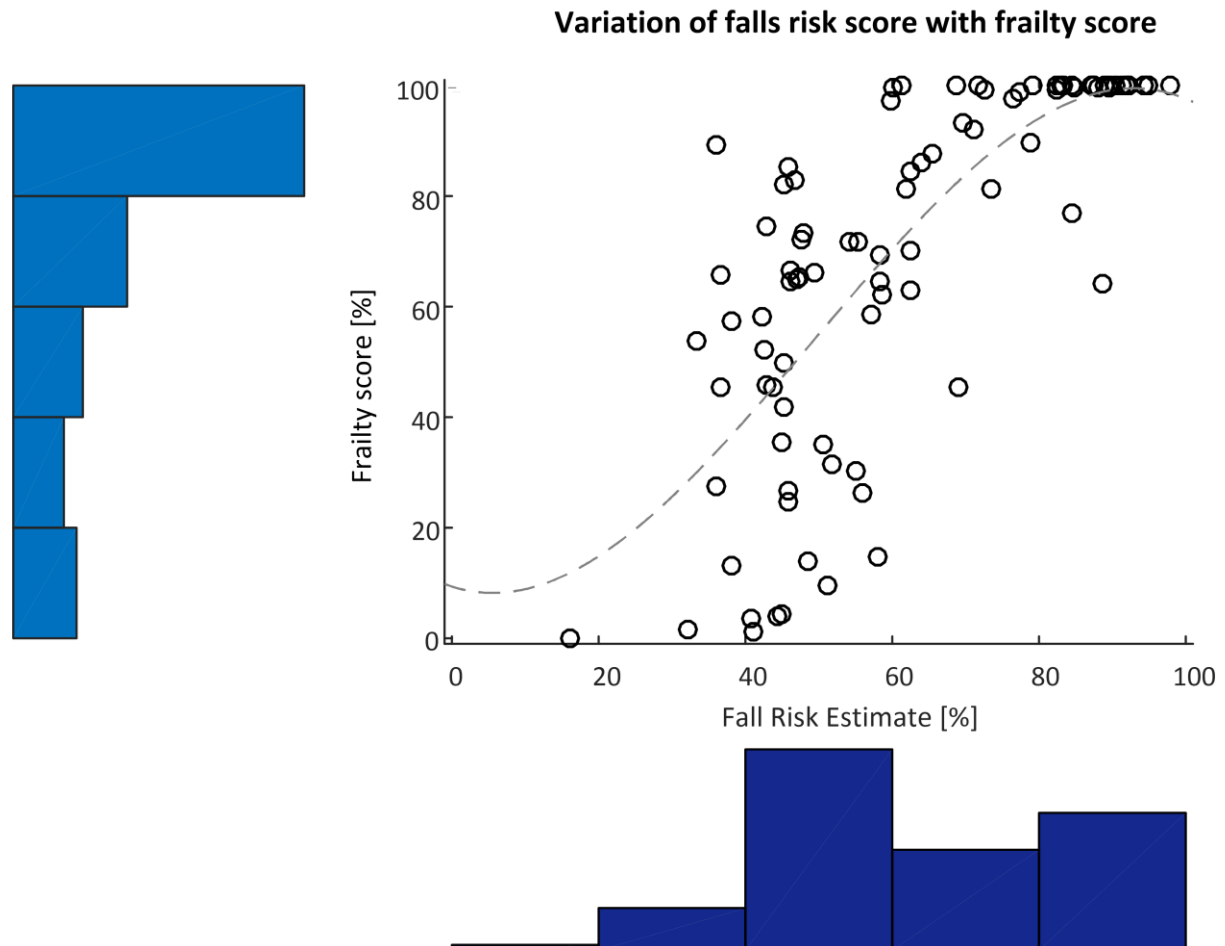
Figure 6: Variation of QTUG™ falls risk scores with QTUG™ frailty scores. Histograms of both scores for this cohort are shown.

Figure 7 below illustrates the effect the presence of polypharmacy has on the QTUG™ falls and frailty risk scores. Patients with polypharmacy (four or more prescription medications) had significantly higher risk of falls and slightly higher level of frailty.
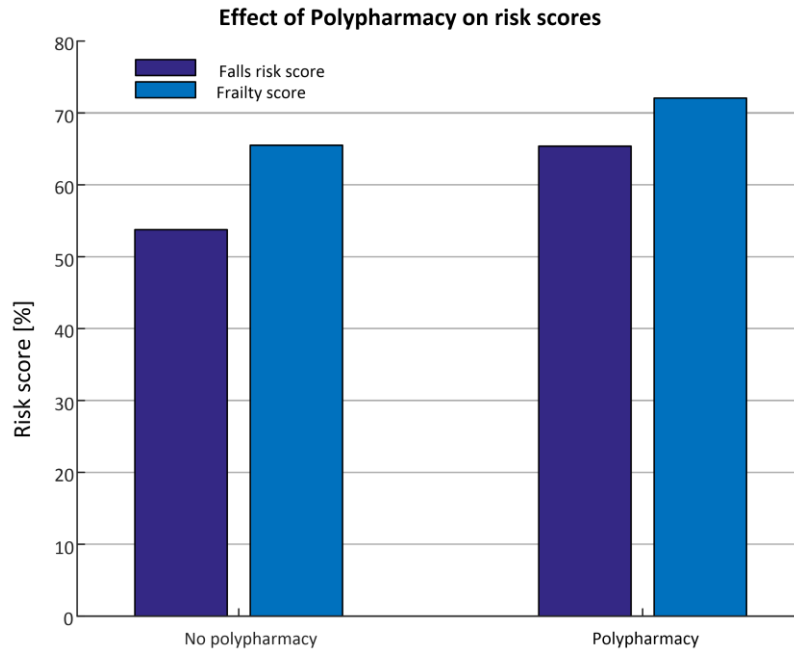
Figure 7: Effect of polypharmacy on QTUG™ falls risk and frailty scores.

Figure 8 below shows the significant effect of self-reported vision problems on falls risk and frailty scores.
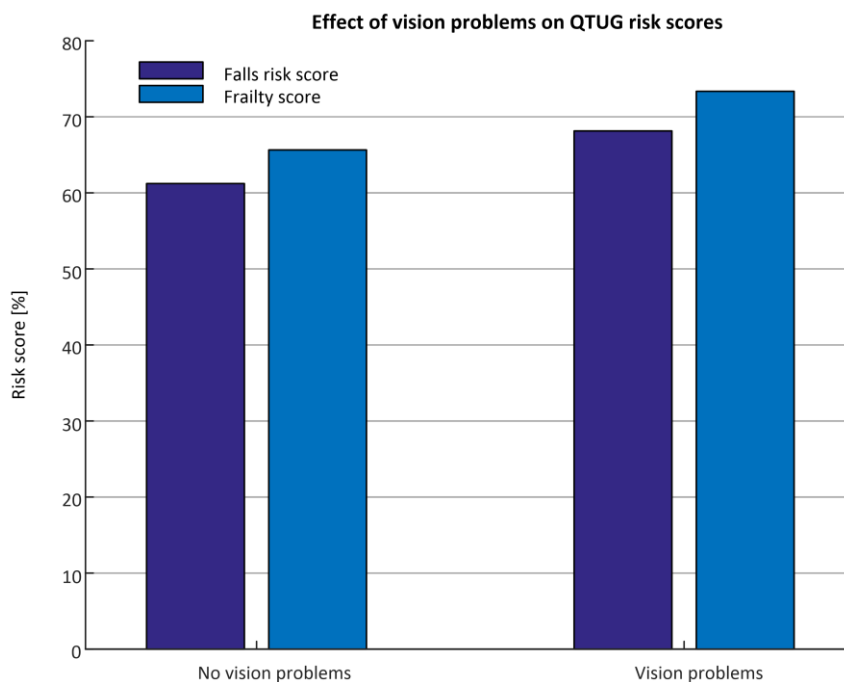
Figure 8: Effect of self-reported vision problems on QTUG™ falls risk and frailty scores.

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Comparison to reference data

Gait and mobility data for each patient is compared to a reference population average for their age and gender. Values outside normal range may indicate mobility impairment or very high performance (see Figure 9 below).

PATIENT COMPARISON TO POPULATION AVERAGE

TUG time (s)
PATIENT — 25.4
POPULATION — 10.58

Mean velocity (cm/s)
PATIENT — 68.2
POPULATION — 101.58

Number of step in turn
PATIENT — 4.0
POPULATION — 1.67
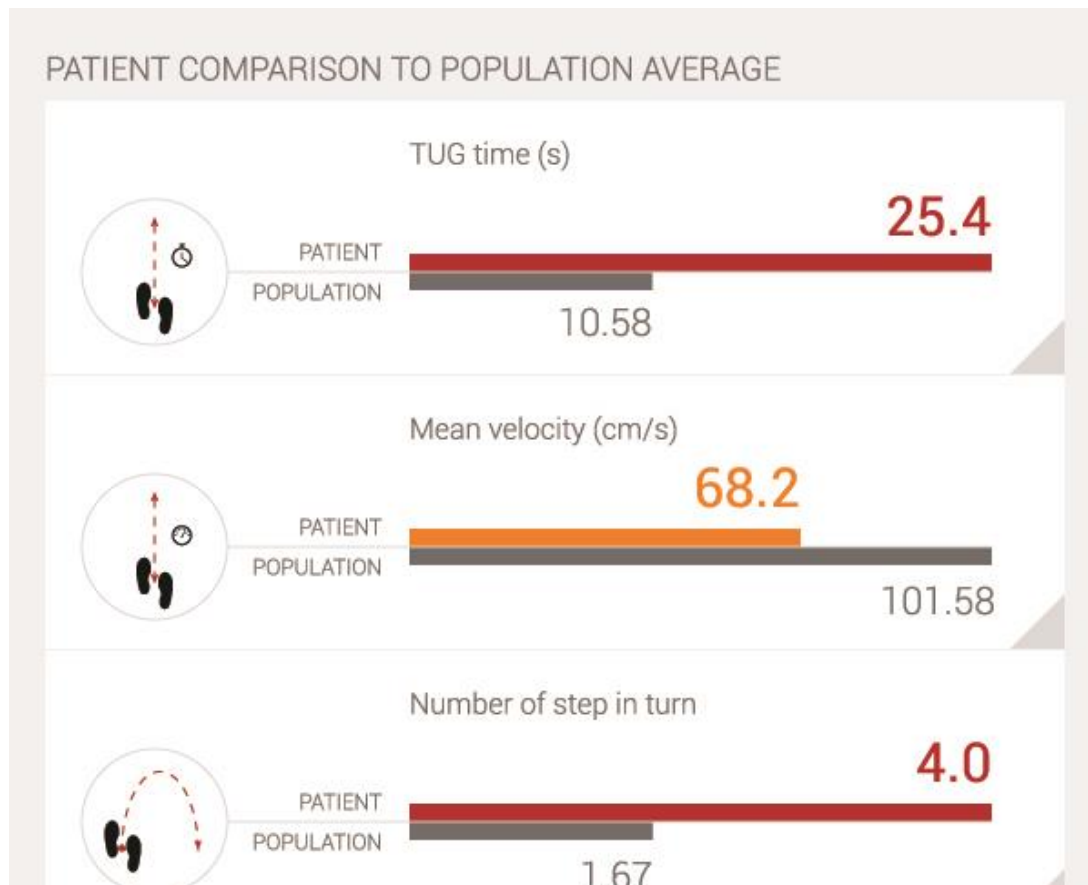
Figure 9: Comparison of a patient's mobility to reference data

Parameter values that may indicate a specific mobility impairment compared to the reference population are highlighted in **Red** (e.g. TUG time value of 20.9s compared to population average of 10.8s), see Figure 10 below. Parameters highlighted in **Green** are considered better than the population average while **Amber** may indicate a tendency towards mobility impairment.

7.8   12.3   20.9

Figure 10: Interpretation of comparison to reference data

Detailed results for selected patients are provided in case studies below. Results illustrate how each patient compares against average values for their age and gender (as calculated using a reference data set of QTUG™ data).

Case studies

A number of individual case studies for patients in this cohort are provided below. Each is intended to demonstrate how the data provided by QTUG™ can be interpreted clinically.

Patient ID: 11495

Male aged 80 years, height 183cm, weight 75kg. TUG time: 8.03s.

ID	Falls History (y/n)	No. falls	TUG time (s)	Falls risk estimate (%)	Frailty score (%)	Comparison to reference data		
						Parameter	Population	Patient
11495	N	0	8.09	40.94	1.25	Stride variability	29.58	2.99
						Cadence	86.89	118.36

Table 2: QTUG™ results for patient 11495. Patient is considered to be at low risk of falls and frailty.

Patient reports no falls in the past year. Patient's TUG time is excellent for their age and gender. Assessment with QTUG™ reports patient has a **low falls** risk and does not exhibit any mobility differences when compared to the reference population. Patient is considered **non-frail** based on frailty score.

The results indicates that patient does not have any substantial gait issues or risk of falls and frailty.

Patient ID: 121071

Female aged 94 years, height 162cm, weight 61. TUG time: 21.96s.

ID	Falls History (y/n)	No. falls	TUG time (s)	Falls risk estimate (%)	Frailty score (%)	Comparison to reference data		
						Parameter	Population	Patient
121071	N	0	21.96	87.42	99.95	None		

Table 3: QTUG™ results for patient 121071. Patient is considered to be at high risk of falls and frailty.

Patient reported no history of falls in the past year. However, patient reports a number of significant clinical risk factors for falls (Polypharmacy, problems with feet, problems with vision). Patient's gait and mobility was found to be within average range for her age but was deemed **very frail** and at **high risk** of falls.

Patient ID: 181618

Male aged 75 years, height 166cm, weight 63. TUG time: 33.10s.

ID	Falls History (y/n)	No. falls	TUG time (s)	Falls risk estimate (%)	Frailty score (%)	Comparison to reference data		
						Parameter	Population	Patient
181618	Y	1	33.10	99.99	99.97	Time to walk to turn (s)	4.94	16.20
						No. of gait cycles	5.47	16.00
						No. of steps	13.02	35.00
						TUG time (s)	12.72	33.10
						Time spent walking (s)	9.46	23.74

Table 4: QTUG™ results for patient 181618. Patient is considered to be at very high risk of falls and frailty.

Patient reported one fall in the past year but did not report many clinical risk factors for falls. Patient's gait and mobility was found to be highly abnormal problematic with significant ambulatory issues. Patient was deemed **very frail** and at **very high risk** of falls.

Patient ID: 349102

Female aged 74 years, height 149cm, weight 46kg. TUG time: 9.07s.

ID	Falls History (y/n)	No. falls	TUG time (s)	Falls risk estimate (%)	Frailty score (%)	Comparison to reference data		
						Parameter	Population	Patient
349102	Y	1	9.07	88.72	64.23	Single support variability (%)	17.20	**70.17**
						Swing variability	18.58	**75.54**
						Double support (%)	0.21	**0.57**
						Swing time	0.46	**0.62**

Table 5: QTUG™ results for patient 349102. Patient is considered to be at very high risk of falls and frailty.

Patient competed the TUG test in a relatively fast time (9.07s), however patient exhibited high gait variability (an established biomechanical risk factor for falls; too much or too little gait variability is associated with falls) and high double support suggesting patient walked slowly with pauses between steps.

Patient reported one fall in the past year and reported a number of clinical falls risk factors (Polypharmacy, vision problems, and dizziness). Patient was deemed **transitionally frail** and at **high risk** of falls and would benefit from intervention.

Patient ID: 8133808

Female aged 86 years, height 146cm, weight 59kg. TUG time: 30.56s.

ID	Falls History (y/n)	No. falls	TUG time (s)	Falls risk estimate (%)	Frailty score (%)	Comparison to reference data		
						Parameter	Population	Patient
8133808	Y	3	30.56	**95.01**	**99.99**	No. of gait cycles	6.30	**18.00**
						Time spent walking (s)	10.08	**28.39**
						Time to walk to turn (s)	5.16	**13.85**
						No. steps	14.59	**39.00**
						TUG time (s)	13.23	**30.56**

Table 6: QTUG™ results for patient 8133808. Patient is considered to be at very high risk of falls and frailty.

Patient was deemed to be at **very high risk** of falls and frailty. Patient reported a significant number of clinical risk factors and exhibited problems with standing, walking and turning.

QTUG™ falls care pathway

Figure 11 below illustrates a suggest falls prevention care pathway integrating QTUG™. The 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%[6]) and personal emergency response (PERS) monitoring.
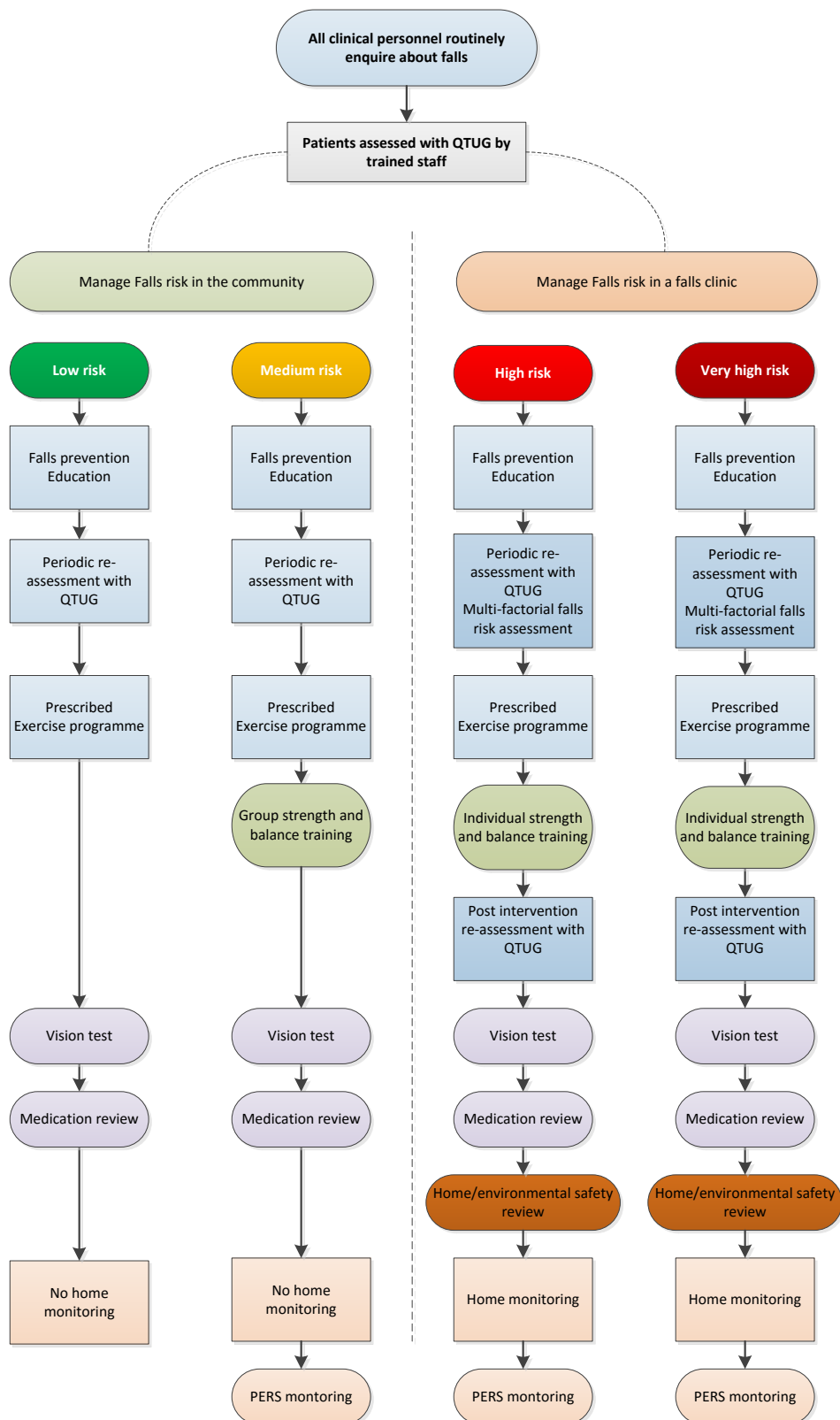
Figure 11: Falls prevention care pathway with Kinesis QTUG™.

Summary

95 older adults were assessed using Kinesis QTUG™ as part of St Vincent's hospital medicine for the Elderly services.

QTUG™ identified falls risk and mobility impairments in patients with no previous history of falls or obvious falls risk. QTUG™ can determine that patients are clinically frail (according to Fried's phenotype). Taken in conjunction with a standard clinical falls risk assessment (to include a falls questionnaire, vision test, polypharmacy etc), QTUG™ may provide greater insights into patient falls and improve management of frailty as a clinical condition.

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Appendix I: Definition of mobility parameters produced by QTUG™

Parameter definition	Description
Falls risk estimate (%)	*Statistical risk of having a fall (defined for community dwelling older adults over 60 years of age).* *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**.*
Frailty estimate (%)	*Statistical estimate of frailty level (defined using Fried's phenotype for patients over 60 years of age* *Values below 50% are considered **non-frail**. Values between 50 and 70% are considered **transitionary**. Values above 70% are **frail** while values above 90% are considered **very frail**.*
TUG test time (s)	*Recording time for entire TUG test as recorded using body-worn sensors.* *Longer TUG times are associated with increased risk of falls[23, 25]. Longer TUG times have also been associated with increased frailty[9, 19].*

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 survival[21]. 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 risk[2]. High gait velocity variability could indicate unsteady 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.*

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)[22] 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 total 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)	*Average number of steps taken per minute during test.*
	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.
Walk time (s)	*Time from first to last heel-strike or toe-off point. Length of time participant actually spends in locomotion during TUG test.*
	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.
Average swing time (s)	*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.*
Swing time variability (%)	*Coefficient of variation in swing time during TUG test.*
	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 [1, 3]. Gait variability has also been associated with cognitive decline and dementia [7, 24]. 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.

Average stance time (s)	*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.*
Stance time variability (%)	*Variation in stance time over TUG test.*
	Longer stance times and increased (as well very low) stance time variability are associated with increased falls risk.
Average stride time (s)	*Time for one stride (time between successive heel-strikes), averaged over all gait cycles.*
Stride time variability (%)	*Variation in stride time during the TUG test.*
	Longer stride times are associated with increased falls risk. Too much or too little stride variability has been associated with increased falls risk[2, 3, 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.
Average step time (s)	*Average time between heel-strike on one foot to heel strike of the opposite foot, measured in seconds.*
Step time variability (%)	*Variation in step time during the TUG test.*
	Longer steps times are associated with increased falls risk. Too much or too little step time variability is associated with increased falls risk[2].
Average double support (%)	*Proportion of a gait cycle spent on both feet during TUG test.*
Double support variability (%)	*Variation in proportion of a gait cycle spent on both feet during TUG test.*
	High values of double support are associated with increased falls risk. High double support variability can indicate highly unstable or unsure gait.
Average single support (%)	*Proportion of a gait cycle (time between successive steps) spent on either foot.*
Single support variability (%)	*Variation in the proportion of a gait cycle spent on a single foot.*
	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)	*Time from 'go' to median gait event of TUG test.*
	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.

Post-turn time (s)	*Time from median gait event of TUG to end of test.*
	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.
Ratio of pre-turn to post-turn times	*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.*
	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.
Time taken to turn (s)	*Time taken to turn through 180°.*
	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 to 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.
Number of steps in turn	*Number of steps taken to turn through 180°.*
	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.
Turn steps/time ratio	*Ratio of the number of steps taken to turn to the time taken to turn.*
	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.

Angular velocity parameters

Forward rotation speed at turn time (deg/s)	*Angular velocity in sagittal plane at median event of TUG test.*
	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.
Range of peak forward rotation speed (deg/s)	*Range of angular velocity in the sagittal plane at mid-swing over entire walk.*
	Larger range denotes increased lower limb rotation in the forward direction. Too much or too little variation has been associated with increased falls risk.
Average peak forward rotation speed (deg/s)	*Average angular velocity in the sagittal plane over entire walk.*
	Linked to minimum ground clearance (also known as toe-clearance)[11, 14] as well as foot speed. Higher foot speed is associated with higher walking speed

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and reduced falls risk. Low minimum ground clearance is associated with risk of tripping[14].

Minimum side-to-side rotation speed (deg/s)	*Minimum angular velocity in the side-to-side direction during the assessment.* *Linked to lateral foot speed, associated with more variable and unsteady walking and higher falls risk.*
Maximum side-to-side rotation speed (deg/s)	*Maximum angular velocity in the side-to-side direction during the assessment.* *Linked to lateral foot speed, associated with more variable and unsteady walking and higher falls risk.*
Average side-to-side rotation speed (deg/s)	*Average angular velocity in the side-to-side direction during the assessment.* *Linked to lateral foot speed and increased unsteadiness in walking.*
Minimum forward rotation speed (deg/s)	*Minimum forward angular velocity in the sagittal plane during the assessment.* *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.*
Maximum forward rotation speed (deg/s)	*Maximum forward angular velocity during the assessment.* *Linked to gait velocity, has also been linked to minimum ground clearance, e.g. risk of tripping, a known falls risk[14]. Decreased values are associated with increased falls risk.*
Average forward rotation speed (deg/s)	*Average forward angular velocity during the assessment.* *Linked to gait velocity, has also been linked to minimum ground clearance [11], e.g. associated with risk of tripping, a known falls risk. Decreased values are associated with increased falls risk.*
Variation in forward rotation speed (%)	*Coefficient of variation in forward angular velocity during the assessment.* *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.*
Variation in side-to-side rotation speed (%)	*Coefficient of variation in angular velocity in the side-to-side direction during the assessment.* *Increased variation in lateral rotation of lower limbs may indicate less stability under locomotion while completing the TUG test.*
Minimum horizontal rotation speed (deg/s)	*Minimum angular velocity in the transverse plane during the assessment.* *Linked to minimum ground clearance (minimum distance from bottom of foot the ground during the swing phase). Low MGC is a known falls risk.* *Maximum angular velocity in the transverse plane during the assessment.*

Maximum horizontal rotation speed (deg/s)	*Linked to minimum ground clearance (minimum distance from bottom of foot the ground during the swing phase). Low MGC is a known falls risk.*
Average horizontal rotation speed (deg/s)	*Average angular velocity in the transverse plane during the assessment.* *Linked to minimum ground clearance (minimum distance from bottom of foot the ground during the swing phase). Low MGC is a known falls risk.*
Variation in horizontal rotation speed (%)	*Coefficient of variation in angular velocity in the transverse plane during the assessment.* *High values are associated with more variable lower limb movement.*

Angular velocity x Height parameters

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

Appendix II: Individual QTUG™ results

ID	Age (yrs)	Gender	Manual TUG	Falls Risk (%)	Frailty score (%)	Falls History
11495	80	M	8.10	40.94	1.25	N
24558	86	M	13.96	62.53	62.93	N
26974	80	F	10.44	46.13	64.72	Y
30183	75	F	12.10	42.59	52.32	Y
42105	76	F	9.56	33.36	53.86	N
110803	68	F	14.35	84.62	76.87	Y
121071	94	F	21.96	87.42	99.95	N
121071	94	F	21.67	66.43	99.91	N
169391	84	M	12.29	45.86	26.50	N
181618	75	M	33.10	68.85	99.98	Y
191539	81	F	10.73	46.22	66.69	N
199228	81	F	22.16	90.31	99.97	N
214093	83	F	14.05	73.61	81.13	Y
219288	74	M	10.24	36.13	27.29	Y
221971	86	M	34.95	83.08	100.00	Y
254814	73	F	7.80	42.32	58.31	N
315977	74	M	11.03	36.54	45.36	Y
315977	74	M	9.07	42.33	8.48	N
328462	90	F	22.26	89.02	99.98	N
333414	78	F	8.97	47.34	65.17	N
336913	78	F	7.71	43.73	45.27	Y
349102	74	F	9.07	88.72	64.23	Y
360487	88	F	27.53	87.17	100.00	N
379133	79	F	11.22	58.72	62.20	N
387182	77	M	15.91	59.71	97.29	Y
387663	80	F	23.43	83.21	99.96	N
398119	85	M	10.73	50.49	35.07	N
402988	81	M	15.32	46.68	83.06	N
409611	81	F				N
411302	90	F	18.35	76.57	97.43	N
421190	84	F	7.90	37.97	57.54	Y
422300	82	F	10.34	58.36	69.20	N
426158	69	F	42.18	61.28	100.00	Y
427063	85	F	15.22	69.74	93.29	Y
431109	87	M	7.71	48.42	13.78	N
433419	87	M	20.99	84.65	99.47	Y
438631	85	F	24.99	92.15	99.96	N
445441	76	F	10.05	49.41	66.00	N
447587	72	M	11.03	45.83	24.53	Y
448016	82	F	25.38	91.82	99.99	Y
451195	89	M	26.85	89.52	99.99	Y
462240	83	F	7.61	42.86	74.32	N
466625	86	M	9.27	57.92	14.62	N
466782	88	M	10.83	55.91	26.16	Y
473613	84	M	11.12	51.71	31.55	N
477412	80	M	9.66	68.96	45.62	N
486566	90	F	12.78	62.45	84.44	Y
520377	85	M	12.00	55.29	71.78	Y

524566	79	F	10.05	58.22	64.61	Y
525225	78	M				N
554368	77	M	11.03	38.11	13.33	Y
556608	80	F	8.19	57.19	58.37	Y
565921	75	M	7.22	32.08	1.43	Y
567045	94	F	30.26	94.89	100.00	N
577368	72	F	21.67	79.17	99.93	N
589584	83	M	9.76	40.92	3.66	N
589974	85	F	9.95	62.47	70.27	N
611354	77	M	11.71	47.98	73.29	Y
612433	75	F	37.29	92.12	100.00	Y
621933	85	F	36.81	91.20	99.99	Y
644119	90	M	21.38	88.07	99.76	N
644897	87	M	43.35	84.61	100.00	N
656501	84	F	12.78	45.38	82.15	N
662533	73	F	10.24	45.15	49.85	Y
665866	93	M	10.54	44.46	4.03	N
669262	89	F	13.56	65.53	87.67	N
684442	83	F	27.14	87.10	99.99	N
686481	98	M	39.35	94.26	100.00	Y
688099	85	F	23.53	89.42	99.45	N
688099	85	F	20.79	86.43	99.17	N
717776	72	M	14.05	36.05	89.29	N
719296	74	F	16.10	77.36	98.64	Y
722241	97	F	31.83	97.73	100.00	N
741698	80	M	17.28	64.10	86.08	Y
757027	89	F	14.15	71.17	91.84	N
758218	83	M	11.61	44.83	35.63	Y
760475	77	F	24.31	87.37	99.97	Y
771223	79	F	26.26	82.39	99.31	N
785917	72	M	7.61	44.93	4.45	N
788052	77	M	13.96	47.74	72.29	Y
789059	82	M	20.79	72.60	99.13	N
802060	79	F	10.05	47.09	65.09	N
810845	84	M	37.20	71.70	100.00	Y
816369	83	F	10.63	54.18	71.91	N
820101	86	M	9.46	51.07	9.70	N
835177	84	M	24.99	82.40	99.98	Y
844013	80	F	17.37	78.97	89.84	Y
846518	90	F	37.98	94.20	100.00	N
847924	77	F	13.17	61.89	81.44	Y
849332	90	F	15.91	45.87	85.15	N
854211	73	F	45.60	29.92	99.94	N
854324	84	M	9.46	54.99	30.23	Y
859632	20	M	5.85	16.03	0.12	N
859644	87	F	24.11	60.11	99.77	Y
859742	81	M	11.32	42.83	45.92	Y
934479	79	M	11.22	45.26	41.86	Y
8133808	86	F	30.56	95.01	99.99	Y
9344799	83	F	13.08	36.48	65.93	Y

Table 7: QTUG Falls risk and Frailty scores for all patients

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