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Novel Digital Gait Kinematic Solution to Improve Frailty

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ABSTRACT

Introduction: Frailty effects a person's health and correlates with mobility and falls. Intervention studies that focus on exercise have demonstrated improved mobility and functional ability in some frailty groups. This study tested a *personalised* intervention programme *automatically generated from digital gait data* on frail older people under the care of the North East London Foundation Trust, Community Hospital setting.

Methods: One hundred and twenty one people, average age 79, who suffered an injurious fall and were under the care of the Community Hospital, completed the personalised intervention programme. Objective gait kinematic data, obtained using GaitSmart™ automatically generated a personalised exercise programme. Each participant received four tests, approximately 3 weeks apart and was provided with a copy of their report plus personalised exercises. Frailty was measured using the Edmonton Frailty Scale (EFS), fear of falling was measured using the Falls Efficacy Scale-International (FES-I) and speed was determined from the gait data (GS).

Results: Five parameters were analysed for all 121 participants at the start and end of the intervention: EFS; FES-I; GS; speed; walking aid. There was a statistically significance between the start and end ($p<0.001$) for all the parameters.

Conclusion: The results demonstrate that addressing frailty using a digital gait solution that sets exercises based on the gait kinematic data, did reverse frailty. This four session programme has shown to improve frailty levels and fear of falling. It also reduced the reliance on walking aids and increased average walking speed from 0.46 to 0.62 m/s.

Keywords: Digital, Gait, Falls, Frailty, Intervention

1 Introduction

Frailty is recognised as a major health condition associated with ageing which has a significant effect it has on health and wellbeing.

In an English Longitudinal Study of Ageing of 5,450 participants, the prevalence of frailty rose exponentially with increasing age, from 6.5% in those aged 60–69 years to 60% in those aged 90 and over

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[1]. On average across OECD countries, the share of the population aged over 65 years was 15% in 2010 and is expected to nearly double in the next four decades to reach 27% in 2050 [2].

Frailty is considered a result of cumulative decline of physiological systems and one of the most problematic issues associated with ageing. Balance and gait impairment are core features of frailty and important risk factors for falls [3]. Frailty is recognised as costly for the patient and society, because of the related adverse events [4]. An observation Cardiovascular Health Study involving 5,317 participants showed that at baseline 72% of frail older people had a problem with mobility compared to 16% for non-frail people. Frailty and intermediate frailty also correlated with incident falls, worsened activities of daily living (ADL) disability, incident hospitalisation and death over 3 or 7 years of follow up [5]. The English Longitudinal study [1] found that 93.2% of the frail participants had problems with mobility, and of those, 63.2% used a walking stick.

As falls correlate to frailty level, addressing frailty will reduce falls. It will also improve mobility and ADLs, whilst reducing hospitalisation and extend lifetime.

Conventionally, exercise rehabilitation programmes have been led by physiotherapists. Many provide standard exercises to all participants have been carried out to ascertain if frailty can be stalled or even reversed. One review which looked at the effectiveness of exercise in the management of frailty, concluded that mobility and functional ability of frail older people improved with some exercise interventions [6]. Another review included six RCTs and looked at whether home-based exercises improved outcomes for frail older people. The conclusion was that there is some evidence that home based exercises may help improve mobility for moderately frail, but not severely frail people [7].

The North East London Foundation Trust (NELFT) covers a region encompassing 2.5 million people of whom approximately 500,000 are over the age of 65. NELFT offers services in the community setting which includes rehabilitation and help to maintain mobility and independence and reduce the number of older people falling. In this study, NELFT tested a novel digital gait kinematic solution on their frail older population, to ascertain whether frailty levels could be reversed.

1.1 Aims and objectives

The primary objective was to ascertain whether a digital health solution based on monitoring gait kinematics could be as effective, or more effective than current physiotherapy led programmes in reversing frailty. Secondary objectives were to improve mobility and reduce the fear of falling.

The overall aim was to improve short- and long-term outcomes with respect to mobility for frail older people under the care of NELFT and reduce reliance on physiotherapists.

2 Methodology

A quality improvement project was undertaken by NELFT. Frailty was determined using the Edmonton Frail Scale (EFS), which has significant association with other screening tools and is quick and easy to implement [8]. A physiotherapy assessment was undertaken to determine mobility and GaitSmart™ used to measure the gait kinematics, demonstrated to provide accurate data in a clinical setting [9]. From the height of the individual, speed was also derived. Fear of falling was measured using the short form Falls Efficacy Scale-International (FES-I) which has been shown to be a good and feasible method to assess fear of falling on older persons [10].

2.1 Participant selection and recruitment

Participants were recruited by physiotherapists working in the Community Hospital (CH) or by the Intensive Rehabilitation Service (IRS), which is a home-based rehabilitation programme attached to the CH. The participants could use any or no walking aid and may be anywhere on the frailty spectrum. Participants were excluded if:

- they suffered from severe dementia or a neurological condition that affects their walking.
- they were unable to perform gentle exercises or were immobile.

One hundred and sixty nine participants were recruited in to the programme over a fifteen-month period. One hundred and twenty one concluded and forty seven did not complete the programme:

- Twenty eight were unable to complete for medical reasons
- Nineteen did not want to complete the programme

All participants had suffered an injury, including 21 who had suffered a hip fracture.

Demographic data for the 121 patients who concluded the study are provided in Table 1

2.2 Experimental GaitSmart protocol

GaitSmart comprises six sensor modules with accompanying straps. The sensors are inertial measurement units (IMUs) and contain three orthogonal gyroscopes and three orthogonal accelerometers. The six sensors are first synchronized using the dedicated software and then disconnected from the computer. Each sensor is switched on and then mounted in to the appropriate pocket within straps. The straps are applied on the lateral sides of the hip, just above the iliac crest, the thigh, just below the greater trochanter and the belly of the gastrocnemius muscle of the calf (see figure 1). The IMU system was applied as described over the participants clothing.

- Patients stand still for five seconds to calibrate the sensors.
- Participants walk at their self-selected speed for 10 metres along a corridor, turn and walk back.
- The sensors are removed from the straps, switched off and attached back to the laptop via the USB connectors.

Poseidon software was used to analyse the data. The observer chooses strides where the stride duration was continuous to within 5% of the mean and from this, the most representative stride of the gait pattern is calculated automatically, i.e. the stride with the lowest error compared to the other strides. The parameters are provided for this stride in tabular form in the patient report. Gait parameters include pelvis, hip, thigh, knee and calf range of motion in the sagittal plane; thigh and calf medial-lateral movement; knee stance flexion; joint and segment symmetry and stride duration. The report compares the gait parameters to a baseline reference in the healthy population, using a red/amber/green Traffic Light Coding.

2.3 The GaitSmart intervention App

NHS and Otago standing exercises used in Falls Exercise Classes formed the database. Physiotherapists ranked each exercise for each gait deficiency identified by GaitSmart. These were classified in order of

merit based on the colour coding from the report. An algorithm was developed with GaitSmart values as the input, and the output was a set of exercises with the highest score. This was the personalised exercise programme for each participant. Four exercises and two best practice activities were provided, specifically to strengthen the muscles and improve the joint movement identified by the results. Participants were provided with assisted and non-assisted exercises.

Figure 1 The locations of straps for the GaitSmart system.



Each test of approximately 10 minutes was performed by a therapist at a location to suit the participant, either in the hospital or in their own home. The programme comprised a series of four tests. The interval between tests was approximately 3 weeks, with flexibility if the participant was unavailable. All exercises were based on the Otago exercise programme [11] or NHS published exercises and excluded exercises

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where the participant was required to sit or lie on the floor. The report and personalized exercise programme were provided to the participant at the end of each of the four tests. The work was in partnership with the physiotherapy group and the entire process was overseen by the lead NELFT physiotherapist and no exercises were changed following review of treatment plans.

Anonymised data, including data on injurious falls and medical conditions that may affect gait, age, height, weight and walking aid were also recorded. The participants also completed the EFS and FES-I questionnaires at the start and end of the programme.

3 Results

Five parameters have been analysed for all 121 participants who concluded the intervention. Table 2 provides the average and standard deviation values at the start and end of the intervention and the statistical significance between the two.

Table 3 states the percentage of patients who improved, remained the same or worsened over the intervention period for each of the five parameters.

Table 4 provides the Pearson Correlation Coefficient between the Gait Score and Speed before and after the intervention. At the start of the intervention there was negligible correlation with speed or Gait Score vs FES-I or EFS, whereas at the end of the intervention, there was moderate to strong correlation. There was a strong correlation between EFS and gait score.

4 Discussions

Frailty is a major health condition that occurs in many older people. It affects an individual's overall health and wellbeing, including a loss of independence regarding ADL disability and falls. A number of physiotherapy led intervention programmes have been tested in clinical trials, which provide a standard set of exercises to all participants. This trial uses a gait monitoring system and a custom designed digital App to provide participants with a smaller set of exercises tailored to their specific weaknesses.

4.1 Changes in frailty

One randomised intervention study on frail older people, average age 80 and average EFS 8.7[12], had a comparable cohort to this trial. Those in the intervention group performed 65 minutes of daily activities, 5 days per week for 24 weeks and those in the control group received the usual standard of care. Their findings were that 31% of the intervention group reversed their frailty score compared to none in the control group, and the average EFS reduced from 8.7 to 7.7. Another study on community dwellers involved a three-month exercise intervention programme, one hour, three times a week [13]. At baseline 87% were pre-frail and 13% were frail. After 3 months, 32% of the pre-frail had become robust, whilst 3% had become frail. Another randomised case control frailty intervention programme. A multifactorial intervention was offered to 120 participants, whilst 121 in the control group received standard care[14, 15, 16]. The intervention programme was based on their frailty level and was designed to help individuals improve their mobility. The intervention resulted in a lower prevalence of frailty in the intervention group compared with the control group at 12 months, but this was not statistically significant with P<0.01 (absolute difference 14.7%; 95% CI:2.4%, 27.0%; P = 0.02).

In this study all outcomes were better than any of the other trials, 71% reversed their frailty score. The average EFS reduced from 7.6 to 5.6 and the difference in frailty was significant with P<0.001.

Table 1 Patient demographics for the 121 patients who concluded the study.

	Age	BMI	% Female
Average ± SD	79 ± 9.4	24.9 ± 4.9	54.2

Table 2 Averages with standard deviations for FES-I, EFS, Gait Score, Walking Aid and Speed at the start and end of the intervention, for 121 patients who concluded the study.

	FES-I *	EFS *	Walking Aid *	Gait Score [%] *	Speed [m/s] *
Start (Average ± SD)	14.9 ± 4.9	7.6 ± 2.8	2.5 ± 1.2	26.1 ± 21.7	0.46 ± 0.17
End (Average ± SD)	11.7 ± 4.8	5.6 ± 2.9	1.8 ± 1.0	46.3 ± 27.3	0.62 ± 0.23

Note. For the walking aid calculation, the scoring system was:

1 - No aid, 2 – Walking stick(s), 3 – Walker, 4 – Frame

*p<.001

Table 3 Changes over the intervention period for five parameters, monitored for the 121 patients who concluded the study.

	Start value	Average change	Improved [%]	Same [%]	Worsened [%]
FES-I (7-28)	14.9	3.3	75	10	15
EFS (0-17)	7.6	2.0	71	16	13
Gait Score [%]	26.1	19.8	76	16	8
Speed [m/s]	0.46	0.16	80.5	0.0	19.5
Walking aid	2.5	0.7	39.7	59.5	0.8

Table 4 Correlations between objective Gait Score and Speed data and EFS and FES-I questionnaires.

	Pearson Correlation [R] Before intervention	After intervention
Gait Score vs FES-I	0.33	0.5
Gait Score vs EFS	0.32	0.58
Speed vs FES -I	0.22	0.48
Speed vs EFS	0.24	0.56

4.2 Speed

Speed is considered a good predictor for adverse outcomes, such as disability in ADL, functional or cognitive decline or increased risk of hospitalisation. One task force [17] studied 27 publications and concluded there is sufficient evidence to state that gait speed identifies autonomous community-dwelling older people at risk of adverse outcomes. It also concluded that the risk of falls correlated with gait disorders and subsequently with gait speed and the fear of falling was associated to slower gait speed. A meaningful change in gait speed has been established at 0.1 m/s, and an increase in gait speed due to intervention increases survival [17]. A separate study concluded that a meaningful change is 0.05 m/s and a substantial change is 0.1 m/s [18]. Speed was an outcome from the Fairhall study [16]. This increased from 0.48 m/s to 0.50 m/s after 3 months and 0.55 m/s after 12 months of intervention, which is not a substantial change.

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In this study the speed increased by 0.16 m/s in 3 months, which exceeds the 0.1 m/s substantial change and far greater than achieved in the Fairhall study [16].

4.3 Gait

Mobility is obtained using a number of short tests and questionnaires [6] which makes it difficult to compare across studies. In this study the GaitSmart (GS) Score provides an objective value representing gait, defined by the range of movement of the limbs and the stride duration. It is a percentage value, where 100% defines normal ranges for all values. In this study the average GS Score increased from 26.1% at the start to 46.3% at the end of intervention period. As no other study has used this parameter, a direct comparison cannot be made. Instead, the GS Score was correlated to FES-I and EFS. At the start there was a weak correlation between the GS Score and both FES-I or EFS, which could be due to the recent trauma they had suffered. However, at the end of the intervention there was a good correlation between the GS Score and EFS (r=0.58) and a moderate correlation with FES-I (r=0.50). This suggests that using gait as the input for the intervention programme educates the participant in the importance of gait.

4.4 Walking aid

The use of a walking aid may impact a person's frailty level, their ability to undertake ADL and their risk of falling. The only study that specifically quotes the type of walking aid related to outcomes following hip fracture from the UK national database [19], where the type of walking aid defined the person's ability to move outside the home. At the start of this study 41% of the participants used a frame or walker, suggesting the average person was housebound and dependent upon help for activities of daily living (ADL). At the end of the intervention only 18% used a frame or walker, meaning 23% more patients could move outside the home..

4.5 Frailty correlation to falls

One study which looked at the prevalence in frailty and falls for different levels of fear of falling [20]. Their findings were that frailty level and number of falls show a clear association with a greater degree of fear. The results from this study support this evidence, with an 11.6% reduction in the fear of falling and frailty level.

Benefits of this study are providing the evidence that digital gait kinematic technology used to generate a personalised exercise programme provide superior results to the conventional approach whereby trained physiotherapists to lead and support the rehabilitation programme.

Limitations of this study are the lack of a control cohort and no long term follow up as it was a quality improvement programme to help NELFT improve outcomes for their frail older population under the care of the Community Hospital.

5 Conclusions

This trial provides the evidence that a digital technology using gait kinematics to produce a personalised exercise programme reduces frailty and minimises the reliance on physiotherapists. It also reduced the reliance on walking aids and increased average walking speed from 0.46 to 0.62 m/s. These improvements are all statistically significant and better than other intervention programmes, which rely on trained physiotherapists to deliver the intervention programme. The traffic light coding in the patient report and

the knowledge that the small number of exercises were chosen to address their specific needs is thought to have motivated the participants to do their exercises. Subsequent tests also encouraged participants to set their own goals, for example to move the right hip range from red to amber. This visual representation helped them to own of their rehabilitation plan. The adaptation of exercises as they progressed also helped maintain motivation and interest.

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CONFLICT OF INTEREST

None

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