The clinical utility of accelerometry in patients with rheumatoid arthritis

Alessandra Prioreschi1, Bridget Hodkinson2, Ingrid Avidon1, Mohammed Tikly2 and Joanne A. McVeigh1

Abstract

Objectives. To assess habitual physical activity levels in patients with RA compared with healthy control participants and to compare these measures with health-related quality of life and disease activity in the RA patients.

Methods. Fifty RA patients [age 48 (13) years] and 22 BMI, sex and geographically matched control participants were recruited. Habitual physical activity was measured using an Actical accelerometer worn on the hip for 2 consecutive weeks. Patients completed the Short Form-36 (SF-36) and modified Health Assessment Questionnaires (HAQ-DI). Disease activity was assessed using the Simplified Disease Activity Index (SDAI). RA patients were further categorized as more physically active (n = 25) and less physically active (n = 25) according to their average activity counts.

Results. The RA group spent more time in sedentary activity than the control group (71% vs 62% of the day respectively, \( P = 0.002 \)) and had bimodal decreases in diurnal physical activity compared with the control group in the morning \( (P < 0.001) \) and late afternoon \( (P < 0.001) \). HAQ-DI, when adjusted for age and disease duration, was negatively correlated with physical activity in the RA group \( (r = -0.343, P = 0.026) \). The more physically active patients scored better than the less physically active patients on every component of the SF-36.

Conclusion. Patients with RA lead a significantly more sedentary lifestyle than healthy controls and show diurnal differences in physical activity due to morning stiffness and fatigue. Higher levels of habitual physical activity may be protective of functional capacity and are highly associated with improved health-related quality of life in RA patients.

Key words: rheumatology, physical activity, accelerometry, functional capacity, quality of life, habitual physical activity.

Introduction

Patients with RA have been shown to have a decreased health-related quality of life (HRQoL) in comparison with the general population [1]. HRQoL (which is defined as the physical, emotional and social aspects of life that are affected by a patient’s disease or their treatment) is a relevant measure of disease activity according to the WHO [2] and feeling well is an important patient outcome, along with management of pain, sleep, fatigue, emotional and physical well-being [1].

The presence of pain limits the ability of patients with RA to function normally, and as a result everyday habitual physical activity levels are reduced [3]. Exercise interventions in patients with RA have been shown to improve sense of wellbeing, decrease morning stiffness, improve sleep patterns and decrease swollen joint counts over time [4], as well as to reduce pain and improve functional ability [5]. Increasing levels of physical activity have been shown to be beneficial for patients with RA without having any adverse effects on disease activity [6]. Most studies have examined the effects of enforced exercise.
interventions on RA disease activity, yet surprisingly little is known about the effects of everyday, spontaneous habitual physical activity levels in patients with RA, and whether patients with increased habitual physical activity levels have better disease activity profiles or feel better. One large study by Sokka et al. [7] did examine self-reported physical activity levels in more than 5000 outpatients with RA in over 20 countries around the world and found that over 70% of these patients did not engage in regular physical activity at all. Furthermore, physical inactivity was more prevalent in patients with lower functionality as assessed by the HAQ. These findings remain to be elucidated using objective measures of physical activity.

Physical activity, as a functional assessment of quality of life, is difficult to assess. Questionnaires and recall diaries are commonly used but are subjective [8], and it is difficult for patients to recall their activity levels accurately, especially for light to moderate intensity activities [9]. Few studies have been performed on RA patients assessing habitual, daily physical activity levels [10]. Two studies have compared energy expenditure levels between patients with RA and controls (average energy expenditure was found to be lower in RA patients than in controls in both these studies), although both made use of subjective measures of physical activity only [11, 12].

Accelerometers are growing in popularity as an objective way to measure physical activity, especially in healthy populations [13], and have been validated using calorimetry and doubly labelled water methods [14]. Actical accelerometers are small, unobtrusive and comfortable and measure acceleration of the limb to which they are attached by detecting low-frequency (0.5–3.2 Hz) forces (0.05–2.0 g) [13]. Acceleration is thought to be directly proportional to muscle forces generated, and therefore to energy expenditure [9]. This theory along with an inbuilt algorithm allows for the conversion of energy expenditure into activity counts, which are generated every minute. These counts can be classified into thresholds, indicating sedentary, light, moderate or vigorous intensity levels [9]. Accelerometers have advantages over self-reported measures, such as being able to objectively track intensity, duration and frequency of an activity without relying on patient recall [15]. Acticals in particular can detect varying levels of activity and movement in multiple planes [10], making them potentially ideal for measuring physical activity in patients with RA, who are generally sedentary and where most movement is functional and of low frequency and intensity, and therefore unlikely to be reported accurately using self-report measures.

Accelerometry has already been used to quantify physical activity levels in other rheumatic diseases, such as OA [16], and to study knee biomechanics in SpA and RA patients [17]. The aims of this study were to assess the potential clinical utility of accelerometry in quantifying habitual physical activity levels and patterns in a group of patients with RA by assessing whether varying levels of habitual physical activity are associated with disease activity and HRQoL and to compare their physical activity levels with those of a healthy group of control participants.

**Participants and methods**

**Participants**

Fifty female patients fulfilling the 1987 ACR classification criteria for RA [18] with a mean age of 48 (13) years were recruited from the Chris Hani Baragwanath Rheumatology Clinic in Soweto, South Africa (RA group). Participants were excluded if they had any co-morbidities, including cardiac, muscle or neurological disorders, that could potentially impact on physical activity, were using any assistive walking devices or were pregnant. The RA group was compared with 22 control participants (control group) who were matched for mean BMI (calculated as weight [kg]/[height (m)]²), race, and sex and were recruited from the same geographical living area as the RA patients so as to closely match the two groups for socioeconomic circumstances. Ethics approval was obtained from the human research ethics committee of the University of the Witwatersrand (M110430 and M110236) and complies with the Helsinki Declaration. All participants signed written informed consent and were free to withdraw from the study at any time.

**Outcome assessments**

**Physical activity**

Actical accelerometers (Respironics Inc., Murrysville, PA, USA) were worn on a velcro belt on the hip of the dominant leg during the day for 2 consecutive weeks (the Actical device has been shown to be most accurate when placed on the part of the body where the motion occurs, and studies have shown the hip to be the only place able to predict free living, habitual activities at all intensity levels [13]). Acticals were removed only when the participants were bathing/showering or participating in any water-based activities. Actical data were recorded in 1 min epochs and data were reduced by removing only full days of non-wear time (as observed in the counts or as reported by the participants), as well as sleeping time as reported by participants. The remaining data (which included daily activities as well as rest periods throughout the day) are referred to as the wear period, which was calculated in a similar manner to that described by Semanik et al. in 2010 [5]. Data for the wear period were divided into thresholds, namely sedentary, light, moderate or vigorous activity according to the activity counts recorded and the inbuilt algorithm calculated by the Actical software (Respironics Inc., Murrysville, PA, USA). Since the participants were found to be extremely sedentary, these data were then expressed as percentage of time spent in sedentary activities on average per day as recommended by Pate et al. in 2008 [19]. The 95th percentile of the activity counts recorded over the period for each participant was also noted in order to eliminate any outliers in maximal activity counts. Activity counts for each participant were also divided into time intervals throughout the day in order to assess daily activity.
habitual physical activity patterns in RA patients (early morning: 6 am–9 am, late morning: 9 am–12 pm, afternoon: 12 pm–3 pm, late afternoon: 3 pm–6 pm and evening: 6 pm–9 pm), and the average activity counts in each time interval throughout the day were compared between the control group and patients with RA. Participants also completed a physical activity questionnaire after the 2 weeks stating the type of activities undertaken over the study period, which was used to assess any water-based activities that were not recorded by the Actical.

**Actical calibration**

It has been recommended that accelerometers be calibrated according to the types of activities they would be recording [20]. All Acticals were calibrated for light ambulatory activity typical of patients with RA by being worn by the same person on the hip of the dominant leg while walking on a treadmill (StarTrac S, Toronto, Canada) for 5 min at a standard speed (5 km/h) and with no inclination. The marker button on the Actical was pressed at the start and end of the 5-min period and data were recorded as average activity counts per minute over the period. The average activity counts recorded for each person over the 2-week period was then divided by the calibrated value that was determined for the respective Actical that the participant wore and this new value was used to classify the participants into more physically active and less physically active groups.

**Functional ability, HRQoL and RA disease activity**

Before being fitted with an Actical, RA patients completed the Short Form-36 (SF-36) questionnaire, a general assessment of HRQoL comprising of eight categories of health, namely physical function, role physical (the role that health plays on physical function), body pain, general health, vitality, social functioning, role emotional (the role that health plays on emotional function), mental health and reported health, all of which are separated into either composite physical health or composite mental health, and combined to give a total SF-36 score where a higher score indicates a better outcome [21]. RA patients also completed a patient global assessment score (PGA) and a modified Health Assessment Questionnaire (HAQ-DI) [22], which is a well-validated RA-specific assessment of functional capacity where the total score ranges from the best possible result (score of 0) to the worst possible result (score of 3). Patients were all assessed by the same physician (B.H.) before commencing the study with a tender joint count (TJC), swollen joint count (SJC) and physician global assessment (MDGA). These, in combination with the CRP concentration in mg/dl and PGA, were used to calculate the composite Simplified Disease Activity Index (SDAI), with cut-offs of <11, >11 and <26 and >26 for low, moderate and severe disease activity, respectively [21].

**Statistical analysis**

Unpaired students t-tests were used to compare all continuous variables between groups. Pearson’s and Spearman’s correlations (for parametric and non-parametric data, respectively) were used to determine correlations between the objective physical activity counts (which were first log-transformed to normalize the data) and subjective questionnaire data as well as disease activity scores within the RA group. A one-way ANOVA was used to assess differences between average activity counts within each category of SDAI. HAQ-DI scores were adjusted for age, as well as disease duration in order to eliminate any confounding variables, and this adjusted mean was correlated with activity counts. The RA group was divided into a more physically active group and a less physically active group according to the median average activity count value for all the patients over the 2-week period in order to assess the SF-36 scores using unpaired Student’s t-tests to compare the two groups. All statistical analyses were done using STATISTICA v10.0 (Tulsa, OK) and a P-value < 0.05 was considered significant. All data are reported as mean (s.d.).

**Results**

The characteristics of the groups are summarized in Table 1. There were no differences between the two groups for any of the variables measured except for age, which was significantly greater in the RA group than in the control group (P = 0.018). The mean BMI of both the RA and the control groups was greater than 30, categorizing participants as obese according to the WHO [23].

The percentage wear time during the day [15 (3) hour awake per day] spent in sedentary activity is shown in Fig. 1. Overall, RA patients spent a significantly greater percentage of their day in sedentary activity than the control participants [71% (11%) vs 62% (11%), P = 0.002], and had a significantly lower value than the control group for the 95th percentile of activity counts recorded [22612 (12255) counts vs 37091 (17650) counts, P < 0.001]. None of the participants took part in any water-based activities.

We assessed how time of day affects physical activity by examining three hourly intervals throughout the day (morning, late morning, midday, afternoon and evening). The average activity counts per three hourly intervals were significantly lower in the RA group compared with the control group for each time category [except for in the evening where there was no difference between the two groups (P = 0.589)], as shown in Fig. 2. These differences between the RA patients and controls was greater in the morning (P < 0.001) and the afternoon (P < 0.001) than in the late morning (P = 0.033) and at midday (P = 0.037).

Table 2 shows a correlation matrix between physical activity counts and various outcome measures. Activity counts were negatively correlated with age, BMI and disease duration and positively correlated with the composite physical health score of the SF-36. There was no correlation between SDAI and physical activity, and there was no difference in the average activity counts of participants who fell into the respective disease classification categories of SDAI (P = 0.976). RA participants had a moderate functional disability according to the HAQ-DI scores shown in Table 1 [22]. HAQ-DI, when corrected for
age and disease duration, was negatively correlated with physical activity ($r^2 = 0.117$, $P = 0.026$) in the group of RA patients as shown in Fig. 3.

There was a wide range of activity counts within the RA group. In order to assess whether SF-36 scores would be different between a more active RA group and a less active RA group, we arbitrarily divided the RA group into a more physically active group and a less physically active group based on the median physical activity count of 1885. The results for the SF-36 between the RA patients (once divided into a more physically active and a less physically active group) are shown in Fig. 4. Both groups scored poorly (<66), yet the more physically active group scored higher than the less physically active group on every component of the SF-36, and significantly higher for the vitality component (54 (17) vs 45 (17), $P = 0.04$), the composite mental health component (53 (17) vs 44 (16), $P = 0.05$), the composite physical health component (47 (19) vs 37 (18), $P = 0.05$), and the total SF-36 score (49 (18) vs 39 (17), $P = 0.03$). The vitality component of the SF-36 was positively correlated with physical activity in the RA patients, and the total SF-36 score trended towards a significant positive correlation with physical activity ($r = 0.269$, $P = 0.097$) as shown in Table 2.

**Discussion**

We have used accelerometry to quantify habitual physical activity in patients with RA compared with healthy, matched controls. Our data support the clinical utility of accelerometry as an outcome measure of habitual physical activity in patients with RA as demonstrated by its association with SF-36 and HAQ-DI. In addition, we
have shown quantifiable differences in physical activity levels over the course of a day between a group of patients with RA and healthy, matched controls. Patients with RA in the present study were more sedentary and less habitually physically active than healthy, matched controls. An average American adult spends 60% of their day in sedentary activities [24]. Our control group spent a similar percentage of their day in sedentary activities, yet our RA group spent almost 2 h more each day in sedentary activities than their healthy matched controls.

Daily habitual physical activity patterns for patients with RA were markedly different to that of healthy controls. RA patients were significantly more sedentary than control participants throughout the day except for in the evening, when the two groups converged to a similar average level of activity. Interestingly, the control participants had two peaks in habitual physical activity levels that were not present in the RA group. These occurred in the early morning and late afternoon. The absence of these peaks in activity levels in the patients with RA is likely to be related to two known symptoms of the RA disease, namely morning stiffness of the joints [25] and fatigue, which tends to peak in the afternoon [26]. Fatigue is an important barrier to physical activity in patients with RA and was shown to be negatively associated with subjectively measured physical activity levels in patients with RA [12]. The ability of the accelerometer to detect the presence of these symptoms, as well as to differentiate between the two groups through measurement of physical activity, makes it a promising tool in the measurement of RA disease outcomes.

Similarly to Sokka et al., we have reported decreased functional ability in patients with RA in association with decreased physical activity levels, but have extended and further unpacked this finding with the use of an objective measure of physical activity. The clinical utility of accelerometry devices could minimize the difficulties associated with language and questionnaire limitations. Functional capacity (as assessed by the HAQ-DI) was shown in the current study to be negatively correlated with objectively measured physical activity in patients with RA. Higher levels of habitual physically activity may have a protective role on functional disability in patients with RA. de Jong et al. [27] in 2003 found HAQ scores to decrease (although not significantly) in a group of patients with RA who underwent dynamic exercise training for 2 years. Also, Walker et al. [28] in 1999 found HAQ scores to be negatively correlated with ambulatory activity in patients with RA as measured by a Numact activity monitor, which only assesses energy expenditure, calculated from number and vigour of steps taken. Henchoz et al. [12] in 2012 found that HAQ was not associated with physical activity, yet their study did not assess physical activity objectively. Despite this, all disease-related scores were found to be significantly poorer in sedentary compared with physically active patients. We show an association between increased levels of objectively assessed habitual physical activity (using a calibrated activity monitor capable of quantifying intensity and frequency of activity within certain thresholds) and functional ability in patients with RA, supporting the utility of the accelerometer as a complementary outcome measure for RA.

Within our RA group, more physically active patients scored better in almost every domain of SF-36 than less physically active patients, and therefore patients with greater habitual physical activity levels reported feeling better than less physically active patients. This is in

### Table 2

<table>
<thead>
<tr>
<th></th>
<th>Spearman R or r value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.441</td>
<td>0.005*</td>
</tr>
<tr>
<td>BMI</td>
<td>-0.361</td>
<td>0.023*</td>
</tr>
<tr>
<td>SDAI</td>
<td>0.172</td>
<td>0.295</td>
</tr>
<tr>
<td>ESR</td>
<td>-0.133</td>
<td>0.419</td>
</tr>
<tr>
<td>CRP</td>
<td>-0.028</td>
<td>0.852</td>
</tr>
<tr>
<td>Disease duration</td>
<td>-0.406</td>
<td>0.010*</td>
</tr>
<tr>
<td>SF-36 Total</td>
<td>0.269</td>
<td>0.097</td>
</tr>
<tr>
<td>Composite mental health</td>
<td>0.189</td>
<td>0.247</td>
</tr>
<tr>
<td>Composite physical health</td>
<td>0.326</td>
<td>0.043*</td>
</tr>
<tr>
<td>Physical function</td>
<td>0.289</td>
<td>0.074</td>
</tr>
<tr>
<td>Role physical</td>
<td>0.173</td>
<td>0.235</td>
</tr>
<tr>
<td>Body pain</td>
<td>0.221</td>
<td>0.177</td>
</tr>
<tr>
<td>General health</td>
<td>0.207</td>
<td>0.207</td>
</tr>
<tr>
<td>Vitality</td>
<td>0.187</td>
<td>0.255</td>
</tr>
<tr>
<td>Social functioning</td>
<td>0.117</td>
<td>0.477</td>
</tr>
<tr>
<td>Role emotional</td>
<td>0.100</td>
<td>0.492</td>
</tr>
<tr>
<td>Mental health</td>
<td>0.031</td>
<td>0.853</td>
</tr>
<tr>
<td>Reported health</td>
<td>0.061</td>
<td>0.712</td>
</tr>
</tbody>
</table>

Correlations were Spearman’s correlations for non-parametric data and Pearson’s correlations for parametric data as applicable. *P < 0.05.
keeping with a previous study that showed exercise to improve the sense of well-being in a group of females with RA of a similar age range to our participants [4]. These findings imply that, although not necessarily having an effect on disease activity, higher levels of habitual, ambulatory physical activity are associated with improved quality of life and sense of well-being, potentially making the disease easier to cope with.

Despite our RA group not nearly meeting the current recommended guidelines for physical activity (30 min of moderate to vigorous activity every day of the week [19]), those that simply had higher habitual physical activity level fared better on assessments of functional status and well-being despite the lack of association with disease activity. It is important to develop healthy, feasible guidelines for patients with chronic limitations of movement, potentially focusing more on increasing light activity and decreasing sedentary activity as an adjunct to increasing moderate to vigorous activity where possible. Patients with RA may need frequent rest breaks depending on the severity of their disease [5], and it might be necessary to develop different Actical cut-off points for activity levels in people with chronic pain conditions in order to allow for the increased periods of non-movement time to be considered. The Actical was able to quantify ambulatory habitual physical activity levels in this group of patients with RA, which is the first step in developing guidelines for this population.

SDAI was not significantly correlated with physical activity. We attribute the absence of a relationship between physical activity and SDAI to the fact that SDAI is comprised largely of tender and swollen joint counts, 26 out of 28 of which are upper limb joints. An activity monitor placed on the hip would measure only ambulatory, lower limb activity and not upper limb activity. It may be necessary to look at the associations between physical activity and deformity of the joints (especially lower limb joints) as assessed by an X-ray or a clinical measure of joint deformity such as the RA articular damage score (RAAD score) [29].

The limitations of this study include the cross-sectional design, which limits the causality conclusions we can draw. While increased habitual physical activity levels were associated with improved well-being and better functional status, it is not clear if this is the cause or the effect. Also we focused only on females, and these results cannot necessarily be extrapolated to males, although the incidence of RA is much higher in females [26]. We also excluded patients who were using assistive walking devices, which limits the extrapolations we can make to RA patients needing to make use of such devices. Lastly, we did not manage to successfully match the ages of the control group with the RA group, and although this was controlled for in the analysis, it is still a limitation to the study.

In conclusion, RA patients have decreased habitual physical activity levels in comparison with healthy, matched controls. The daily physical activity patterns of the patients with RA do not show the same bimodal peaks seen in healthy control participants and are likely to be related to periods of morning stiffness and fatigue. The activity counts recorded by the Actical accelerometer correlate well with the HAQ-DI, giving the Actical construct validity as a novel outcome measure in RA. Furthermore, patients with higher physical activity levels scored better with regards to the SF-36 in both physical and mental domains. A longitudinal study is needed to assess the
responsiveness of physical activity to changes in disease activity.

Rheumatology key messages

- Actigraphy counts are negatively correlated with HAQ scores in patients with RA.
- More physically active RA patients scored better than less physically active patients on many components of SF-36.
- RA patients demonstrated quantifiable bimodal decreases in daily physical activity in the morning and late afternoon.

Funding: This work was supported by the National Research Foundation, the Connective Tissue Disease Research Fund and by a Carnegie Corporation Transformation Programme Large Research Grant.

Disclosure statement: The authors have declared no conflicts of interest.

References