Lack of exercise in both humans and dogs has been linked to health problems. Here we report on preliminary experiments using a small bodyworn GPS unit to monitor the amount of exercise (distance travelled and speed) in dogs and their handlers during off-lead routine walks. We found that dogs travel longer distances and at higher speed compared to their handlers and that some dogs have to deviate from their preferred and energetically optimal speeds in order to be 'compatible' with their handlers.

INTRODUCTION
Lack of daily exercise is often reported to be linked to health problems in both human and animals, in particular but not limited to obesity and type II diabetes [1, 2, 3]. In questionnaire based studies dog ownership has been shown to positively influence exercise patterns in humans [4] and lack of exercise has been linked to obesity in dogs [3]. Also exercise has been shown to affect objective kinetic gait analysis in dogs with osteoarthritis [5]. However, problems have been identified with questionnaire based studies identifying different interpretation of 'physical exercise' between participants and researchers [6] emphasizing the need for a more objective and easy to use means of quantifying exercise amount in humans and canines. The objective of this study was to undertake a pilot study into the feasibility of using GPS to objectively quantify exercise amount during daily off-lead dog walking routines. We hypothesized that dogs would travel longer distances than their handlers, travel at higher speeds and would have to deviate from their metabolically or mechanically optimal speeds [7, 8] to adapt to the activities of their handlers.

METHODS
Dogs and Owners
18 volunteers and their dogs were recruited to participate in this study. Pairs of dogs and owners were recruited from members of staff of the Royal Veterinary College and through personal contact of the investigators. Volunteers were asked about their daily routines and only pairs of dogs and owners were included who reported that their daily exercise was at least partly 'off-lead'. Owners were asked to give information about age, height, weight and breed of their dogs and optionally their own age.

Data collection
Each dog owner was asked to perform four dog walks with recording of GPS over a period of one week. Owners were instructed on the use of a commercially available GPS watch with a WAAS enabled SIRFstarIII™ chipset and were instructed to wear these around their wrist. An additional identical GPS unit was attached to a commercially available dog harness with a mass of 73g. A harness was used rather than a standard collar to avoid slippage of the GPS unit and to ensure clear sky view since the number of satellites has been shown to influence quality of GPS data [9]. GPS units were set to log data once per second rather than triggered by activity to include periods of rest into the data collection. Owners were asked to stick to their normal daily routines.

After return of the units, data were downloaded from the GPS watches using a proprietary software package and data were exported from the software in the form of text files including information about date, time, latitude, longitude and distance travelled. Speed was calculated from differentiation of distance travelled.

RESULTS AND DISCUSSION
Study population
The dogs recruited in this study varied in breed (13 different breeds), size (mean 51 cm, range 28 to 70 cm) and mass (mean 25 kg, range 8 to 40 kg). Dogs were on average 6.2 years of age (range 4 to 11 years), while their handlers reported a mean age of 36 years (range 19 to 73 years).

Distances travelled and speeds used were compared between dogs of different sizes. Distances travelled and speeds used were compared between dogs and handlers with a paired t-test on a walk by walk basis. Statistical significance was set to 0.05.

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Collected data
In total 18 volunteers returned data from 4 walks each, so 72 walks were completed. The majority of walks (86.1%) returned usable data (defined as GPS data without dropouts due to lost reception from the satellites e.g. caused by tree coverage or large buildings). This restriction of the use of GPS
should be taken into account when designing future studies and owners should be made aware of this to achieve high quality data. However, if 'real world' everyday data is to be collected, then a tradeoff between data quality and unwanted effects on the behavior of the participants has to be achieved.

Distance travelled
The average distance travelled by the handlers (the distance of the route of the walk) was 2.36 km; on average, dogs travelled 2.91 km, 23.3% further than their handlers (P=0.0001). On a walk by walk basis, distances differed between dog and handler by as much as 165%, meaning that the dog travelled 2.6 times the distance than the handler. Further studies with larger populations of dogs and handlers should be undertaken investigating the effect of amongst other factors age, obesity levels and health problems on the distance travelled by both dogs and their handlers.

Speed
The average speed across all handlers was 1.3 m/s and the average speed across all dogs was with 1.6 m/s higher than for their handlers (P<0.0001) with a maximum difference of 139% between dog and handler. When normalized to body size, the dogs travelled at a mean Froude number of 0.05 (range: 0.02 to 0.2).

One a walk by walk basis, large difference were observed qualitatively between the individual pairs of dogs and their handlers (see figure 1 for two examples). While some dogs followed the speed pattern of their owners closely (Fig 1A), other dogs showed larger divergence from the speed pattern of their handler showing two, possibly three preferred speeds (Fig 1B).

Further investigations should have a closer look into the relationship between preferred speeds and the corresponding gaits of dogs, in particular since height differences between different breeds of dogs mean that the preferred speeds of some dogs might match more or less well to the preferred speed of their handlers. Thus some dogs might be required to travel more frequently at speeds other than mechanically and/or metabolically optimal [7, 8]. This should be taken into account when advising on the amount of exercise during rehabilitation or weight loss exercise programs.

CONCLUSIONS
This pilot study showed that dog handlers ranging from 19 to 73 years of age were able to successfully collect GPS data during routine walks. Our preliminary data supports the hypothesis that dogs compared to their handlers cover on average larger distances at higher speeds. Speed histograms revealed qualitative differences in the speed patterns of the dogs in relationship to the preferred walking speed of their owners. Further studies should investigate more closely the relationship between body size of the dog and the speed and gait patterns during off-lead exercise allowing collection of real world data about preferred speeds as a result of interaction between canines and humans.

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Figure 1. Typical examples of histograms of speed of dog (magenta) and handler (blue) during a routine daily walk measured with a standard GPS watch. Two different patterns can be observed. A: dog and handler travel at similar speed; B: dog and handler travel at different speeds. Two (possibly three) preferred speeds can be seen that are different from the speed of the handler.