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CORRELATION BETWEEN INTERNAL KNEE JOINT LOADS AND VIBROARTHROGRAPHY FOR DETECTING KNEE-JOINT DISORDERS – A PILOT STUDY

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INTRODUCTION

Knee Osteoarthritis (KOA) is the leading cause of long-term disability mostly affecting people above 65 [1]. An early detection of KOA can play a crucial role for choosing the right intervention to postpone the degenerative process. Arthroscopy offers a relatively low-risk, albeit invasive assessment of joint surfaces [2]. Imaging tools are less invasive alternatives but can impose radiation, and a low correlation between image diagnostics and pain intensity has been shown in the literature [3]. Vibroathrography (VAG) has been proposed as a simpler diagnostic tool for KOA. Due to the versatility and flexibility of the necessary equipment, the method can be used during both dynamic movement and static situations to record the vibrations and sounds from the intra- and extra-articular components with e.g. accelerometers [2,4]. Since the signal from degenerated joint surfaces is reported to differ from healthy knees in both time (amplitude) and frequency domain [5], VAG measurements have the potential to detect e.g. cartilage loss.

A critical parameter for cartilage damage and KOA development in general is the internal joint loads and the distribution of these [5]. A common approach for estimating them is the use of musculoskeletal models based on inverse dynamics analyses. This approach uses the kinematics as input, which requires recording equipment, e.g. a marker-based motion capture system. We investigated the relationship between the amplitude of VAG signals and knee joint loads. If successful, the investigation may enable assessment of the latter in a clinical setting based on VAG measurements only.

METHODS

Four healthy subjects (2 males and 2 females, age: 27.1 ± 1.6 years, height: 173.5 ± 9.1 cm, body mass: 64.9 ± 8.1 kg) were asked to perform five trials of three different speed: normal gait (self-selected speed), fast gait (faster than normal), and slow gait (slower than normal). The trajectories of 55 markers were recorded with a marker-based motion capture system (Oqus 300 series, Qualisys AB, Gothenburg, Sweden) with a sample frequency of 240 Hz and the ground reaction forces (GRF) were sampled at 2400 Hz using three force plates (AMTI OR6-5-2000, Advanced Mechanical Technology, Inc., Watertown, MA, USA). These data were used as input to a musculoskeletal model in the AnyBody Modeling System (AMS) (AnyBody Technology, Aalborg, Denmark), estimating the internal joint loads (see Fig. 1).

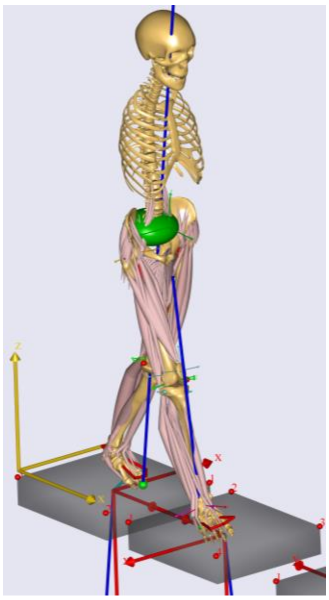

Fig 1: The model used in AMS with the blue lines representing the GRF.

The VAG signals were measured with a sample frequency of 1000 Hz from three accelerometers placed on the subjects' right shank inspired from [4] (see Fig. 2). They were amplified and converted into SI unit ($m\ s^{-2}$) and band-pass filtered with Kaiser windowed finite impulse response with cut-off frequency [10-250 Hz] and a filter order of 447.

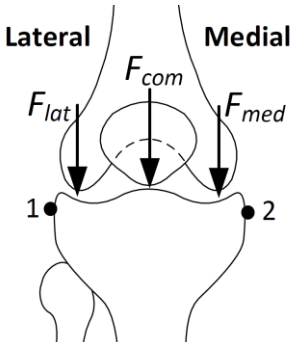

Fig 2: Placement of the two accelerometers at lateral and medial tibia epicondyle (1 and 2 respecively). The forces investigated are F_{com} = total compressive load, F_{lat} and F_{med} = the lateral and medial condyle loads respectively.

The average rectified value (ARV) was computed for both accelerometers to express the VAG amplitude.

The correlation between the mean ARV VAG through the stance phases and the mean knee compression load as percentage of body weight (BW) through stance phases was investigated. This was conducted for both the total compressive force (F_{com} in Fig. 2), compared to the sum of the mean ARV VAG from the two accelerometers, and lateral and medial condyle force (F_{lat} and F_{med} respectively in Fig. 2), compared to the mean ARV VAG from accelerometers 1 and 2, respectively.

RESULTS AND DISCUSSION

Fig. 3 and 4 indicate some correlation for relative total knee compressive force and medial condyle force respectively with correlation coefficients of R^2=0.40 and R^2=0.41 respectively, whereas lateral condyle force showed a very poor relation (R^2=0.11).

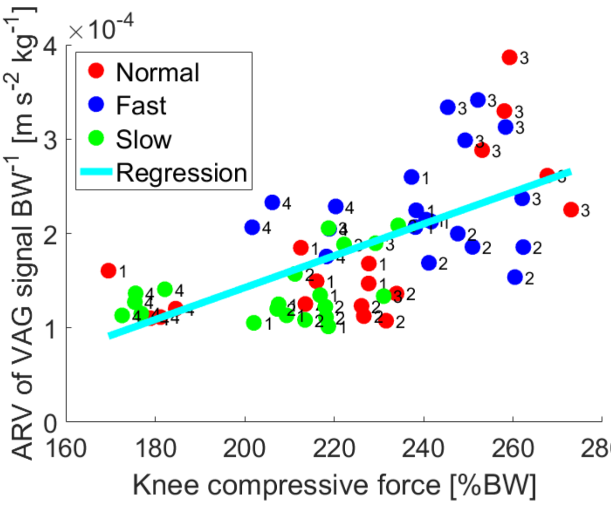

Fig 3: Linear relation (R^2=0.40) between the amplitude of the VAG signal and knee compressive force. The colors indicate gait speed and numbers represent the participants.

A positive relationship is observed between relative joint force and gait speed within each subject with fast walk causing the highest loads, except for subject 3, who has normal and fast gait almost on top of each other. This variation may be due to the self-selected speeds, which could have been pre-defined.

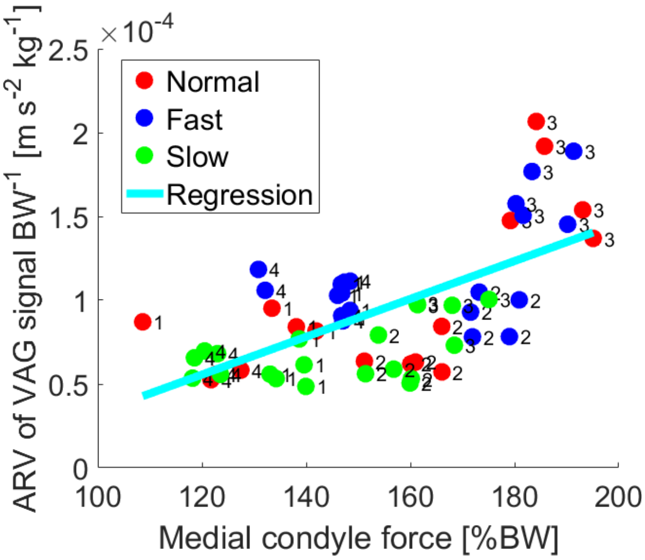

Fig 4: Linear relation (R^2=0.41) between the amplitude of the VAG signal and knee compressive force. The colors indicate gait speed and numbers represent the participants.

CONCLUSIONS

A slight tendency to estimate higher joint loads for high amplitude of VAG signals was observed with increase in gait speed in healthy subjects. More subjects are needed to determine a possible correlation between these two parameters. Likewise, studies with KOA patients are warranted.

The VAG signal depends on other factors than joint loads such as the joint angular velocity, which further investigations will look into.

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