INTRODUCTION:
Standard clinical scores in orthopaedics such as the KSS, HHS or WOMAC suffer from a ceiling effect, subjectivity and pain dominance masking function. New objective functional outcome tools for routine clinical follow-up are required to monitor the increasingly demanding patients and to validate the benefits of new surgical techniques and devices for which the power of classic scores is missing. Inertia based motion analysis (IMA) is a promising technique suitable for routine clinical application as it is fast, cheap and requires no gait lab with specialist personnel.

It was shown that using IMA for gait analysis is capable of distinguishing healthy from pathological subjects but gait was not demanding enough for certain orthopaedic differences. Stair climbing is a more demanding task which assessed by IMA could identify age related degradation of motion and diagnose meniscal tears. However, the need for a standardized stair case makes this test not feasible for routine follow-up within the confines of the orthopaedic practice. Sit-to-stand from a chair is a demanding task of daily activity which can be assessed in the consultation room, is faster than a gait or stair test and is part of the “Timed Up & Go” test validated for orthopaedic application. This study investigates the suitability of an IMA assessed sit-to-stand test as an orthopaedic outcome measure by asking whether a) simple motion parameters can show differences between healthy subjects and b) can differentiate healthy subjects from knee arthroplasty patients.

METHODS:
Rising (sit-to-stand) from a chair and sitting down (stand-to-sit) at comfortable, self-selected speed was measured three time using a triaxial accelerometer (range: ±2g, f=100Hz, 64x64x13mm, m=54g) attached to the lower sacrum with a tight elastic belt. The chair (no armrests) was height adjustable (legs at 90° flexion) to level the effort for different body lengths. A rest period of ca. 1s between each motion allowed for the full natural completion of the movement.

Subjects measured were 70 healthy volunteers without orthopaedic treatment or complaints (f/m=48/22, mean age: 48.2yrs, range: 18-79) and a pathological group of 20 patients with knee osteoarthritis indicated for unilateral total knee replacement (TKR, Biomet Vanguard), measured at 1-10 days pre-op (f/m=11/9; mean age: 65.6yrs, range: 45-79; KSS: 43.5, range: 5-65). The healthy group was split into two subgroups, an age-matched “Old” group (>50yrs: nY=32, mean age: 65.2yrs) and a “Young” group (<50yrs: nY=28, mean age: 28.0yrs).

Motion parameters derived using acceleration thresholds (Fig 1) were the time to stand up (tup), time to sit down (tdown), the difference between rising and sitting down (tdown-tup) and the combined time of rising and sitting down (tup-down). The combined time was used as means values and per individual repetition.

Groups were compared (old vs young, healthy vs pre-TKR, male vs female) using the Mann-Whitney or the student t-test after testing for normality. Correlations between motion parameters and age, height, weight and BMI were tested by multiple regression analysis (p<0.05).

RESULTS:
In healthy subjects the mean time (±SD) to rise from a chair was lower (tup=186±25ms) than to sit down (tdown=206±25ms), a fact found in 66/70 individuals. Both avg. tup (-17ms) and tdown (-13ms) decreased significantly between first and last repetitions while the difference tdown-tup (19-22ms) remained nearly constant though with high variation (SD=26ms). No differences were found between men and women.

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<tr>
<th></th>
<th>Healthy Young</th>
<th>Healthy Old</th>
<th>Pre-TKR</th>
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<tbody>
<tr>
<td>Avg. tup</td>
<td>184±22</td>
<td>188±28</td>
<td>306±99</td>
</tr>
<tr>
<td>Avg. tdown</td>
<td>200±23</td>
<td>212±30</td>
<td>315±71</td>
</tr>
<tr>
<td>Avg. tup-down</td>
<td>202±27</td>
<td>224±43*</td>
<td>347±100*</td>
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<tr>
<td>Avg. tdown-down</td>
<td>-15±27</td>
<td>-24±24</td>
<td>-9±61*</td>
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Table 1: Motion parameters (p<0.05: *young vs old, °healthy vs TKR).

Older subjects had slower averages up and down but a sign. difference was only found for first effort to sit down (young: 202±27ms; old: 224±43ms; p=0.01, Table 1). Only for the older subjects a sign. reduction of tdown was measured between subsequent repetitions (first and second). Parameters were not sign. correlated to height but to weight and BMI, especially BMI and tdown-down (r=0.41, p<0.001).

All motion parameters were sign. slower with higher variance for the pre-TKR versus the healthy subjects, even when compared to the age-matched subgroup (except tdown-down). Like with healthy subjects tdown and tdown decreased between first and last repetition. Threshold values could be defined to delineate healthy from pathological performance, e.g. tup>220ms (6/70=9% vs 17/20=85%, p<0.01) or tdown>240ms (4/70=6% vs 18/20=90%, p<0.01, Fig 2) producing high test sensitivity (90%, C.I. 72-98) and specificity (94%, C.I. 89-97). In some false positives (3/6) originally unknown orthopaedic problems were identified in retrospect.

Fig. 1: Typical acceleration signal from sit-stand-sit test.

Fig. 2: Time from stand-to-sit for healthy subjects and pre-TKR patients.

DISCUSSION:
The simple accelerometer assessed sit-stand-sit test produced rising and descending times similar to values reported for a smaller group using sophisticated equipment (vector stereography, electrogoniometry) unsuitable for routine clinical application (tup=191ms, tdown=197ms). The reduction of times between repetitions indicates a learning effect which must be controlled in clinical assessment. Although energetically less demanding, sitting down was the slower task in most subjects indicating that balancing a backwards motion is more challenging than rising forward. Also age related degradation was found at significant level only for the first effort to sit down when negotiating chair height, position and stability is new and thus most difficult. Parameters were not correlated with height supporting the requirement of a height adjustable chair for comparable sit-stand-sit assessment. Weight and BMI were correlated with sit-stand-sit performance which can make it difficult to distinguish functional capacity from strength and fitness in such a test.

Healthy and pathological motion could be distinguished with high sensitivity and specificity even versus age matched controls supporting the use of the accelerometer assessed sit-stand-sit test to complement classic outcome scores with an objective functional component.

REFERENCES:

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