Improvements in joint kinematics recorded during therapy sessions are not reflected in more traditional pre- and post-therapy functional assessments

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Introduction: The benefits of a therapeutic intervention are typically established and quantified by measuring functional ability before and after a defined period of therapy. The movements tested during such assessments may not be related to the content of therapy and each movement, position or task is usually tested 1-3 times only. One method to overcome such limitations is kinematic analyses of stereotypical movements such as gait or reaching for objects. Active and passive range-of-motion are also commonly employed. Such methods provide information about *what* has changed and *how much*, but little evidence for *why*, *where* and *how* such improvements are mediated.

Aims: This study investigated joint movement of the more-affected upper-limb *during* post-stroke Wii-based Movement Therapy.

Methods: Twelve hemiparetic patients participated, they were aged 22-75 years (mean 60.6) and 4-150 months (mean 40.5 months) after a unilateral stroke. Wireless telemetry was used to record joint kinematics at early- (day 2), middle- (day 7-8) and late-(day 14) therapy during the formal sessions of a standardised 14-day protocol of Wii-based Movement Therapy. This rehabilitation strategy uses the Nintendo Wii and Wii Sports games of tennis, golf, boxing, baseball and bowling in a structured and targeted program that is individually tailored for each subject. Goniometers were placed across the shoulder, elbow and thenar interphalangeal joints. Electrogoniometer signals were continuously recorded during the therapy session and analysed for movement duration, excursion, velocity and acceleration. The results were compared to conventional upper-limb active and passive range-of-motion and functional movement ability including the Wolf Motor Function Test, the upper-limb motor subscale of the Fugl-Meyer Assessment and the quality of movement subscale of the Motor Activity Log.

Results: Maximum movement velocity ($p<0.001$), movement acceleration ($p\leq0.02$) and deceleration ($p\leq0.004$) improved for both shoulder and elbow, whereas activity-specific improvements in joint excursion were seen at the shoulder ($p\leq0.002$) but not elbow. The thenar goniometer signal proved unreliable in this configuration and was not extensively analysed. Shoulder and elbow improvements were not correlated with changes in upper-limb active or passive range-of-motion but reflected improved motor control at these joints. One specific example of improved motor control was that patients initially used a single motor strategy for all tasks. By the end of therapy they could appropriately grade the motor output. In golf this was seen as the selection of appropriately and selectively graded movements for putting and driving. In bowling patients were able to correct movement errors, changing the movement trajectory to strike any remaining pins. Functional movement significantly improved, particularly for the timed tasks of the Wolf Motor Function Test ($p=0.02$) and Fugl-Meyer Assessment ($p=0.01$). The movements specifically trained in Wii-based Movement Therapy were generalised into unrelated activities of daily living measured as improvements in the quality-of-movement subscale of the Motor Activity Log ($p<0.001$).

Conclusions: This study demonstrates that the use of off-the shelf video games can be used in a structured program to improve the quality of movement trained during post-stroke rehabilitation. Our data suggest that range-of-motion assessments do not adequately capture changes in functional movement promoted by Wii-based Movement Therapy, regardless of whether active or passive measurements are employed. We have also demonstrated that the improvements in functional movement ability after 14-days of Wii-based Movement.

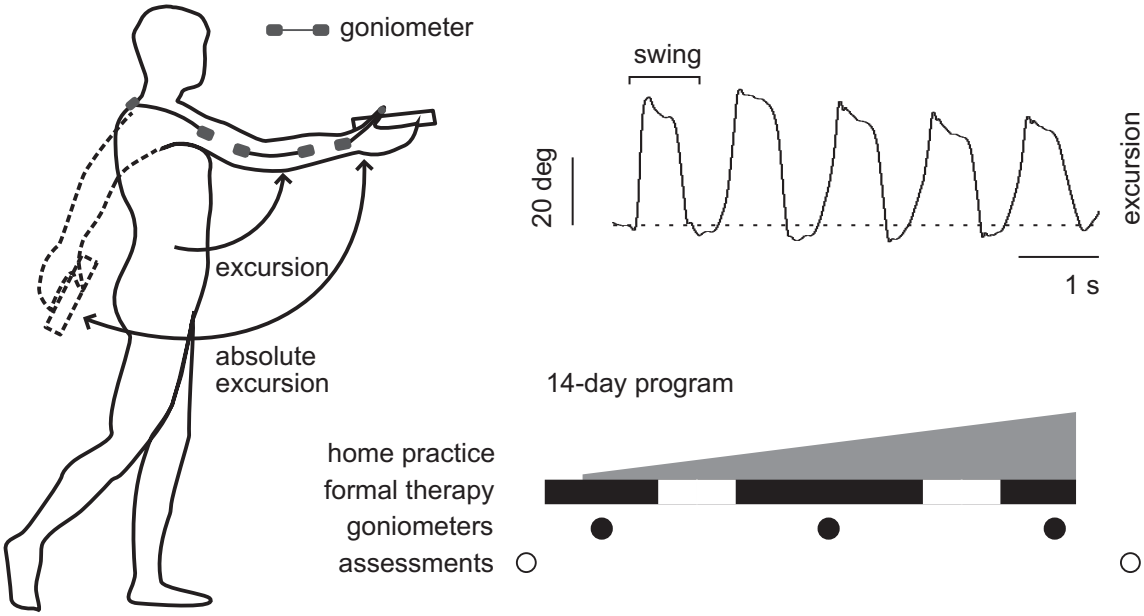

Fig 1. Wii-based Movement Therapy 14-day protocol, goniometer placement and an example of raw data for shoulder joint excursion during Wii bowling.

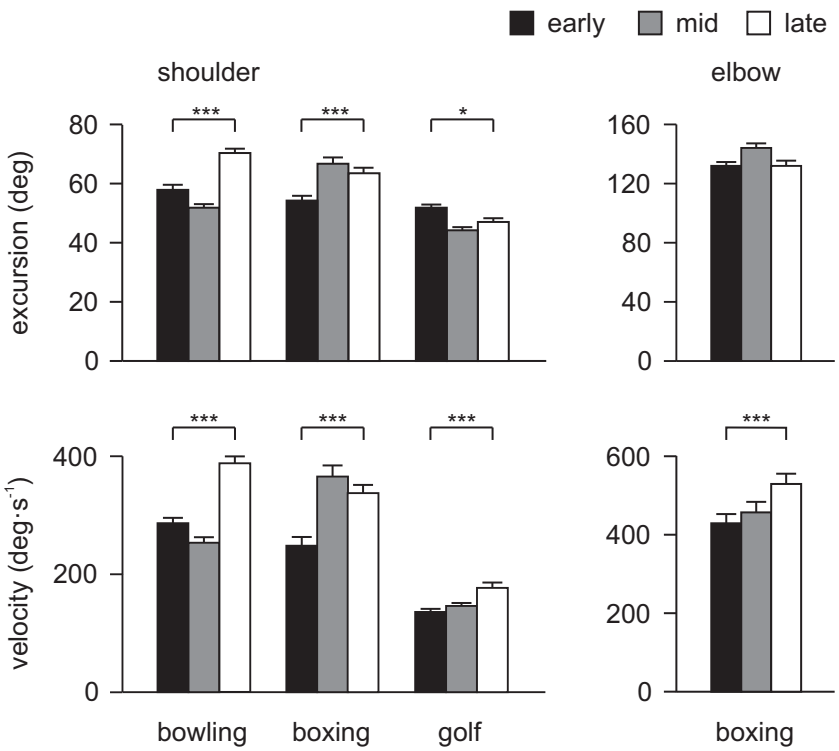

Fig 2. Results. Pooled data (n=12) for joint excursion (top) and velocity (bottom) for the shoulder (left) and elbow (right) joints. *** $p<0.001$, * $p<0.5$. Note that the reduction in shoulder excursion during golf represents increased motor control seen as smaller movements during golf putting.