CHAPTER III

METHODS

3.1 Introduction

This chapter describes the study design, characteristics of participants, materials, procedures, data processing and statistical analyses.

3.2 Study design

Experimental cross-sectional study design was used to investigate the EMG of abdominal muscles while performing AH in four positions; crook lying, prone lying, four-point kneeling and wall support standing. The order of testing was randomized using a 4 x 4 balanced Latin square therefore four sequence combinations included in Table 3.1 are possible (Portney and Watkins, 2000). Additionally, each testing position precedes and follows the others only once.

Table 3.1 The order of testing position of abdominal hollowing was randomized by a 4 x 4 balanced Latin square method (Portney and Watkins, 2000)

Testing sequence	Order of testing position			
1	A	B	D	C
2	B	C	A	D
3	C	D	B	A
4	D	A	C	B

A = Crook lying, B = Prone lying, C = Four-point kneeling, D = Wall support standing.

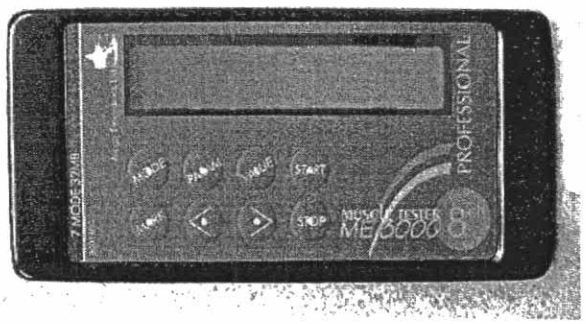
3.3 Participants

This study was approved to conduct by the Ethical Review Committee for Research Involving Human Subjects and/or Use of Animal in Research, Health Science Group of Faculties, Colleges and Institutes, Chulalongkorn University, Thailand (Appendix B). Thirty-two healthy participants, who had never practiced AH, aged between 20-30 years, participated in this study. This number of participants was considered to be sufficient as it is the minimum representative number of population (Portney and Watkins, 2000). To decrease the EMG artifact due to adipose tissue lying between the surface electrodes and the tested muscles, the participants with abdominal and supra-iliac skinfold thickness less than 20 millimeters were recruited (Neumann and Gill, 2002). They were excluded if they had had history of LBP and any abnormalities of the spinal column or abdominal regions such as fracture, surgery, burn, and cancer.

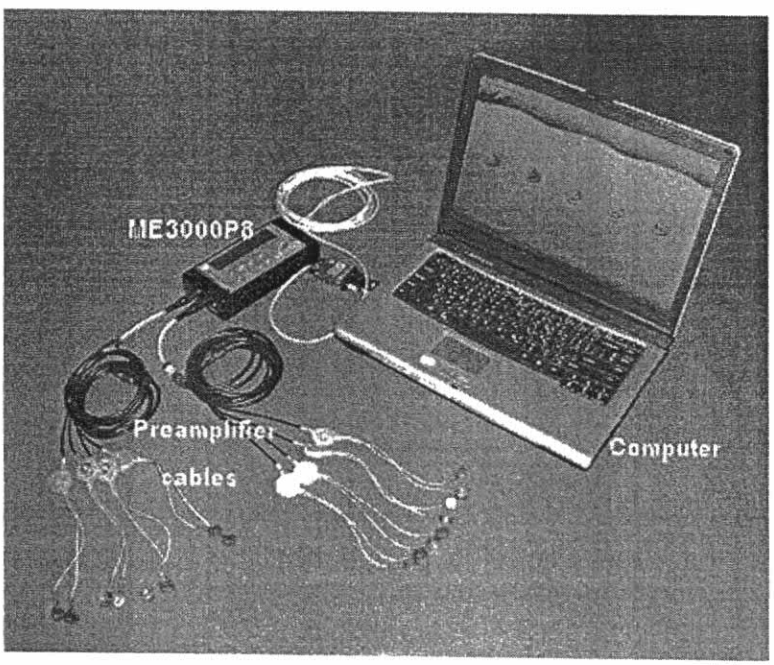
3.4 Materials

3.4.1 ME3000P8 EMG system® (Mega Electronics Ltd, Kuopio, Finland)

All raw EMG signals were pre-amplified with an overall gain of 375, filtered to produce a bandwidth of 8-500 Hertz and the common mode rejection ratio 110 decibel. The data was analogue to digital converted and simultaneously displayed on a personal computer monitor which being recorded for subsequent analysis. The rate of sampling was 1000 hertz. In order to investigate EMG activity of RA, EO and TrA/IO, three channels method was used in this study (Figure 3.1).



A



B

Figure 3.1 Surface electromyography.

A = Muscle Tester ME3000P8®, B = Overall system including ME3000P8, preamplifier cables and computer.

3.4.2 Silver/silver chloride surface electrodes (Medicotest Blue Sensor® type M-00-S, Ambu, Denmark)

The EMG activity of the three abdominal muscles (RA, EO and TrA/IO) was measured by attaching self adhesive disposable bipolar silver/silver chloride surface electrodes to the

skin overlying the muscles. All electrodes had one centimeter in diameter and were placed with a center-to-center spacing less of 2.2 centimeters (Ng et al., 1998). Two snaps for active electrodes and one snap for reference electrode. An adhesive tape was also used to prevent sliding of the surface electrodes during measurement.

3.4.3 Jamar 5028 Medical skinfold caliper® (Preston, MI, USA)

This instrument with 1-millimeter resolution (Figure 3.2) was used to measure the abdominal skinfold thickness in two areas. Firstly, the right abdominal skinfold was measured at two centimeters lateral to the navel. Secondly, the right supra-iliac skinfold was measured at a diagonal fold along the natural angle of the iliac crest in the anterior axillary line (McArdle et al., 2000).

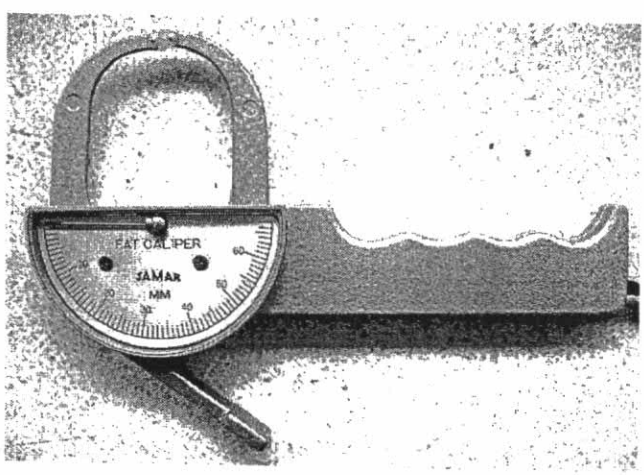


Figure 3.2 Skinfold caliper.

3.4.4 Fine sandpaper

Fine sandpaper was used to scrub the epidermis to decrease skin resistance.

3.4.5 Alcohol

Seventy percent ethyl alcohol was used with the cotton ball to clean and decrease skin resistance.

3.5 Procedures

This study was conducted at the laboratory room number 2203, Department of Physical Therapy, Faculty of Allied Health Sciences, Chulalongkorn University. Participants received the details of the procedures and signed consent form before participating in the study. The procedures started with the training session, electrode placement, recording of EMG activity during MVC, and recording of EMG activity during AH in four positions.

3.5.1 Training session

All participants were trained to perform AH in four positions, the order of the position was randomly assigned using a 4 x 4 balanced Latin square (Table 3.1). The training followed the standard protocol suggested by Richardson and Jull (1995) until they were able to correctly perform the AH. Briefly, the researcher instructed the participants to do abdominal breathing and hold their expiration. The participants gently pull the navel in and up by not allowing any movement at the spine, rib and pelvis (Norris, 1995; O'Sullivan, 2000; Richardson and Jull, 1995). The lumbar spine was kept in neutral position. After the navel was drawn closed to the spine, the participants were instructed to breathe normally while holding the abdominal contraction for 10 seconds. Verbal and tactile feedback were given to the participants (Ng et al., 2002a).

3.5.2 Electrode placement

The skin underlying the electrode was prepared to reduce skin impedance. The skin was shaved any noticeable hair, slightly scrubbed using a fine sandpaper and cleaned with an alcohol (Dankaerts et al., 2004; Hogrel, 2005). All abdominal muscles were recorded on the right side using surface electrodes placed parallel to the muscle fibers (Figure 3.3). The RA electrodes were placed in a cephalud/caudad orientation at two centimeters inferior to the navel and one centimeter lateral to the midline (Beith et al., 2001). The EO electrodes were placed diagonally on the inferior edge of the eighth rib superolateral to the costal margin (Beith et al., 2001; Ng et al., 2002a). TrA and IO run parallel and fuse together at inferior and medial to ASIS (Marshall and Murphy, 2003).

The area of TrA and IO fused together is called TrA/IO showed pre-activation as the results of TrA (Lehman et al., 2005; Marshall and Murphy, 2003). The TrA/IO electrodes were placed horizontally at two centimeters inferior and medial to the ASIS (Marshall and Murphy, 2003). A reference electrode for each muscle was placed adjacent to the pair electrodes of that muscle.

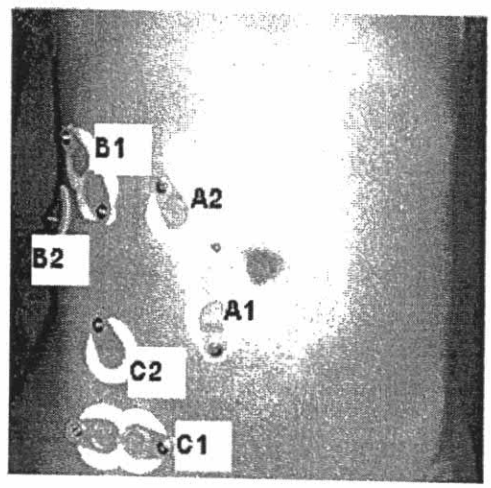


Figure 3.3 Location for attaching surface electrodes.

A1, B1, and C1 represented pair electrodes of rectus abdominis, external abdominal oblique, and transversus abdominis / internal abdominal oblique, respectively. A2, B2, and C2 represented reference electrodes of rectus abdominis, external abdominal oblique, and transversus abdominis / internal abdominal oblique, respectively.

3.5.3 Recording the EMG activity during MVC

All participants were asked to perform two maneuvers which were expected to generate maximal EMG activity for each of the three abdominal muscles. These maneuvers were performed once in crook lying and then in sitting. A pilot study was conducted and it was found that the MVC of the three abdominal muscles (RA, EO, TrA/IO) could be investigated from one exertion (Appendix D). Consequently, each participant performed six maneuvers in total.

For crook lying, the participants were positioned supine with knees flexed at 90 degrees and their arms across their chests (Drysdale et al., 2004). The ankles were stabilized by an assistant. For sitting position, the participants sat near the edge of the plinth, hips and knees flexed at 90 degrees, and their arms across their chests. The three maneuvers were trunk flexion, trunk flexion with rotation to the left, and trunk flexion with rotation to the right. For all maneuvers, the resistance to movements was applied manually by a researcher.

In order to encourage the participants to produce the maximal contraction, the researcher provided consistent and continuous verbal feedback. The researcher asked the participants to hold the position at their maximum effort against the resistance (see Appendix C for detail). The participants were also instructed to avoid any jerky contractions in order to decrease the chance of injury. Each maneuver was held for five seconds with a 2-minute rest between trials to prevent muscle fatigue (Ng et al., 2002a). The maneuver either in crook lying or sitting position that produced greater EMG activity of each muscle was chosen as a reference value for normalization.

3.5.3.1 Trunk flexion

According to the arrangement of muscle fibers, this maneuver was recommended for providing the MVC for RA muscle (Ng et al., 2002b). However, it can also produce MVC for EO and TrA/IO in some participants. Although this study investigated in lower part of abdominal muscles that suggested suitable maneuver by leg lowering, recent studies used technique resisting of upper part (Kendall et al., 1993). Using EMG activity in order to compare with other studies is a result to choose these maneuvers.

In crook lying position, the participants were asked to flex their upper trunks until their inferior angles of scapulae were lifted off the plinth. The researcher applied resistance on participants' shoulders in a symmetrical manner (Figure 3.4A). In sitting position, the participants were asked to slowly bend forward to approximately 30 degrees and held this position against manual resistance applied through both shoulders (Figure 3.4B).

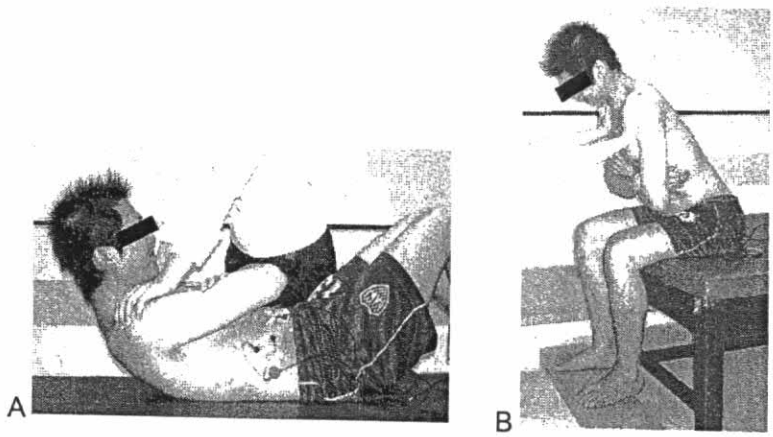


Figure 3.4 Trunk flexion maneuvers used for measuring the maximal voluntary contraction of the abdominal muscles in (A) crook lying and (B) sitting positions.

3.5.3.2 Trunk flexion with rotation to the left

According to the arrangement of muscle fibers, this maneuver was recommended for providing the MVC for EO muscle (Ng et al., 2003; Stevens et al., 2006). However, it can also produce MVC for RA muscle in some participants.

In crook lying position, the participants were asked to flex and rotate their upper trunks towards the left until their inferior angles of right scapulae were lifted off the plinth. The researcher applied a resistance through the right shoulders of the participants (Figure 3.5A). In sitting position, the participants were asked to slowly bend forward to approximately 30 degrees and rotate towards the left while holding this position against manual resistance applied through the right shoulders (Figure 3.5B).

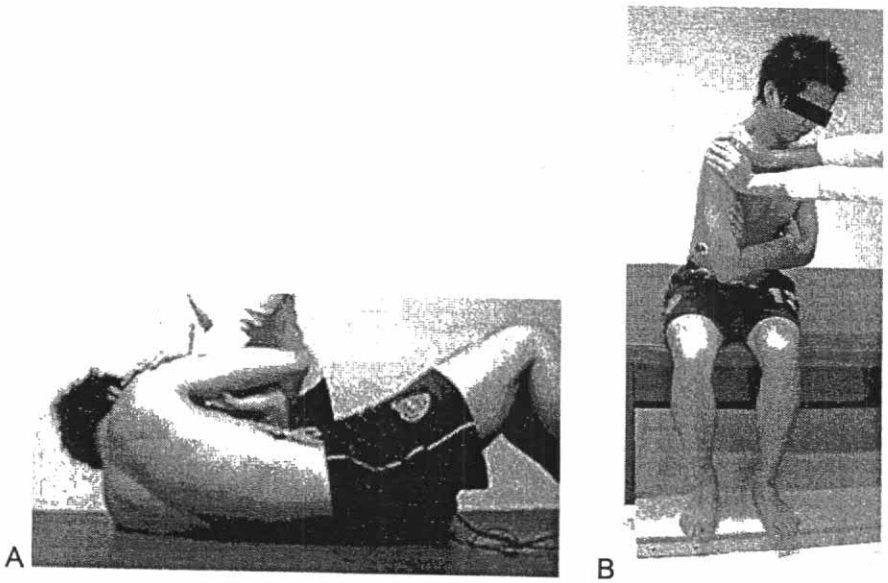


Figure 3.5 Trunk flexion with rotation to the left maneuvers used for measuring the maximal voluntary contraction of the abdominal muscles in (A) crook lying and (B) sitting positions.

3.5.3.3 Trunk flexion with rotation to the right

According to the arrangement of muscle fibers, this maneuver was recommended for providing the MVC for TrA/IO muscle (Ng et al., 2002b; Stevens et al., 2006). However, it can also produce MVC for RA muscle in some participants.

In crook lying position, the participants were asked to flex and rotate their upper trunks towards the right until their inferior angles of left scapulae were lifted off the plinth. The researcher applied a resistance through the left shoulders of the participants (Figure 3.6A). In sitting position, the participants were asked to slowly bend forward to approximately 30 degrees and rotate towards the right while holding this position against manual resistance applied through the left shoulders (Figure 3.6B).

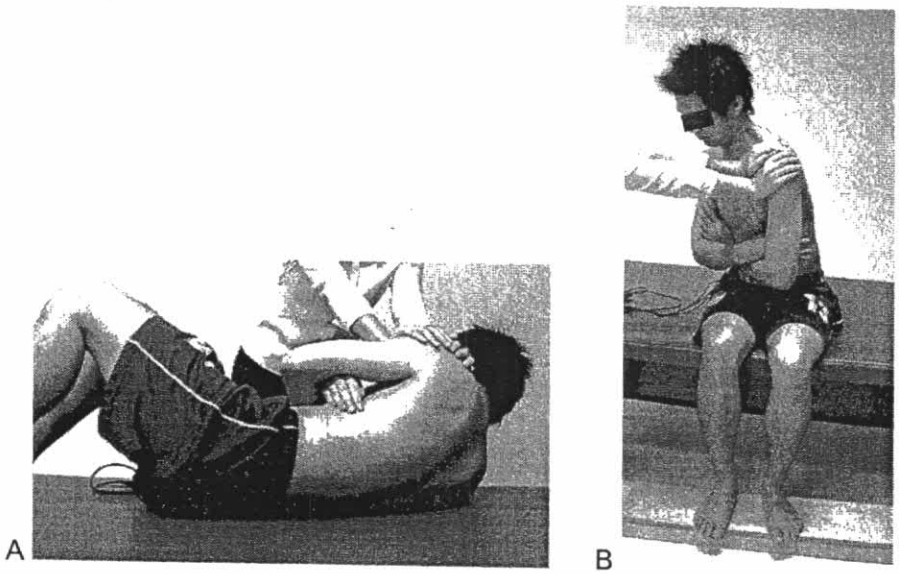


Figure 3.6 Trunk flexion with rotation to the right maneuvers used for measuring the maximal voluntary contraction of the abdominal muscles in (A) crook lying and (B) sitting positions.

3.5.4 Recording of EMG activity during AH

The TrA/IO was the local muscles that used to measure in this study by collected EMG activity at one point because their muscle fibers run parallel and fuse together (Marshall et al., 2005). The EO and RA were the global muscles that used to measure in this study.

All participants were set in one of the four starting positions according to the group sequence they were assigned. They were required to perform the AH for 10 seconds, three times in each position, with 1-minute rest between each time. One-minute rest was also allow between each position.

3.5.4.1 Crook lying position

The participants were asked to lie supine on a plinth with their knees flexed at 90 degrees and their arms were placed by side (Drysdale et al., 2004). The lumbar spine was set in neutral position by positioning the anterior superior iliac spine (ASIS) in the

vertical line with the PSIS (Richardson et al., 2004). Once they were set in the correct position, they were instructed to perform AH (Figure 3.7).

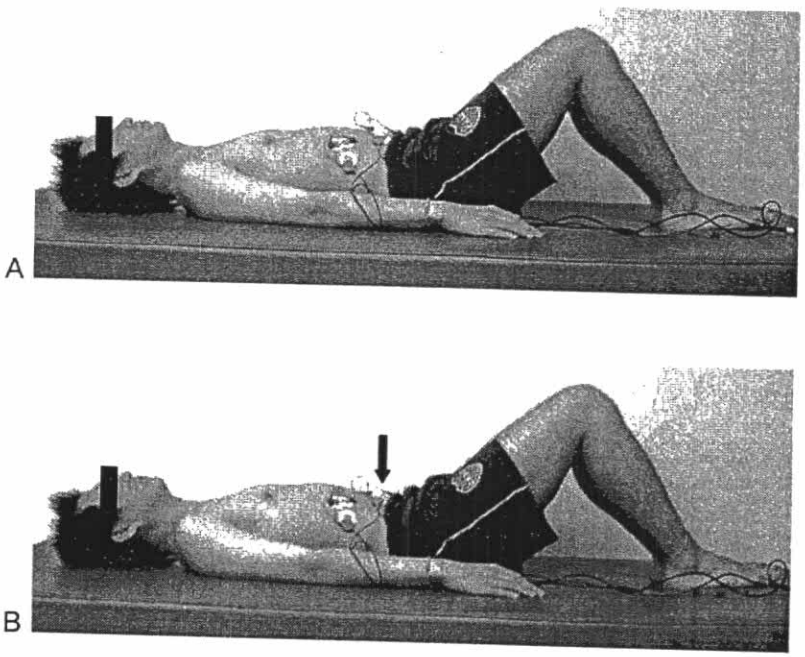


Figure 3.7 Abdominal hollowing in crook lying position.

A = Preparing abdominal hollowing with the correct lumbar neutral position and B = Performing abdominal hollowing (Arrow showed contraction of abdomen).

3.5.4.2 Prone lying position

The participants were asked to lie prone on a plinth with a small pillow placed under the ankles and the arms were placed by side (Richardson and Jull, 1995). They were allowed to rotate their heads to either left or right, whichever felt comfortable. The lumbar spine was set in neutral position with the criterion used for crook lying position (Richardson et al., 2004). Once they were set in the correct position, they were instructed to perform AH (Figure 3.8).

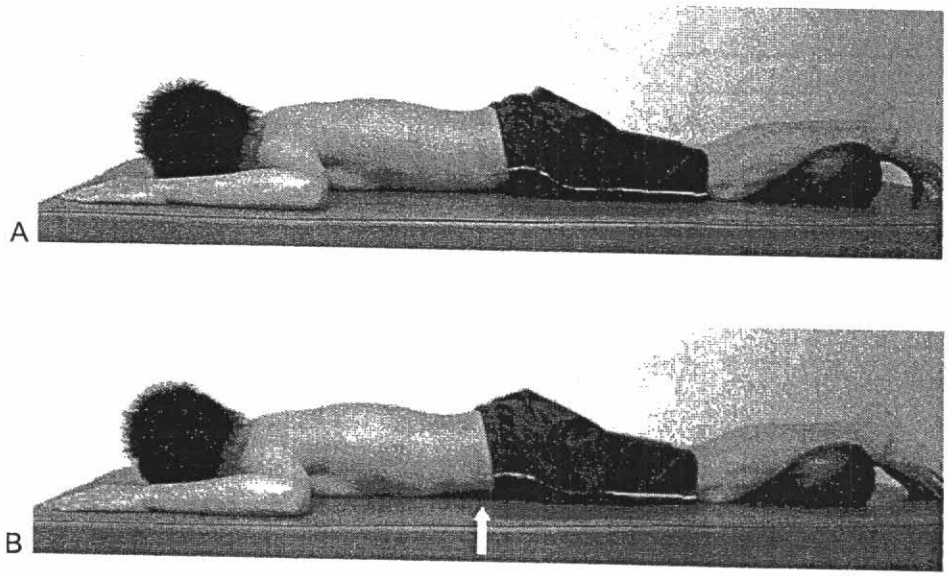


Figure 3.8 Abdominal hollowing in prone lying position.

A = Preparing abdominal hollowing with the correct lumbar neutral position and B = Performing abdominal hollowing (Arrow showed contraction of abdomen).

3.5.4.3 Four-point kneeling position

The participants were asked to look at the floor with the ears in horizontal line to the shoulder joints, the knees directly below the hips and the wrists directly below the shoulders (Norris, 1999). A small pillow was placed under the ankles (Richardson and Jull, 1995). The neutral position of the lumbar spine was set such that the ASIS and PSIS were aligned vertically. For the participants whose their ASIS and PSIS could not be aligned vertically due to the very stiff spine, the neutral position was set about midway between full lumbar flexion and full lumbar extension Once they were set in the correct position, they were instructed to perform AH (Figure 3.9).

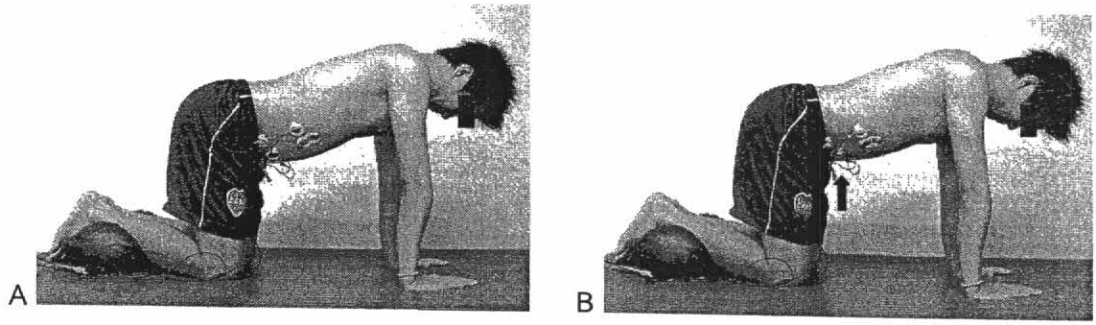


Figure 3.9 Abdominal hollowing in four-point kneeling position.

A = Preparing abdominal hollowing with the correct lumbar neutral position and B = Performing abdominal hollowing (Arrow showed contraction of abdomen).

3.5.4.3 Wall support standing position

The participants were asked to stand with their backs against the wall while their hips were slightly flexed and their knees were extended. The distance of the wall to their heels was six inches (Norris, 1995). The neutral position of the lumbar spine was set by aligning ASIS in horizontal line with PSIS. Once they were set in the correct position, they were instructed to perform AH (Figure 3.10).

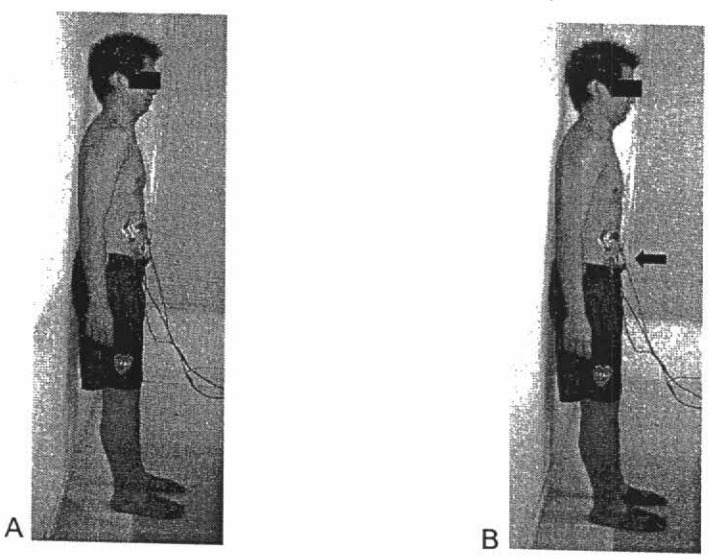


Figure 3.10 Abdominal hollowing in wall support standing position.

A = Preparing abdominal hollowing with the correct lumbar neutral position and B = Performing abdominal hollowing (Arrow showed contraction of abdomen).

3.6 Data processing

The raw surface EMG signals generated during both the MVC and AH were smoothed with the root mean squared (RMS) technique. The mean EMG activity over a 1-second period was used to calculation for both MVC and AH. For the MVC, there was collected at the highest area. The base line with 1-second period of MVC was subtracted from the highest data of MVC. The result from subtracting was indicated the RMS of MVC. For the AH, there was collected at 2-seconds period prior the end of EMG activity (Figure 3.11) (Beith et al., 2001). This aimed to standardize the data collection period for all participants. The base line with 1-second period of AH was subtracted from the activity of AH at 2-seconds period before end of performing. The result from subtracting was indicated the RMS of AH.

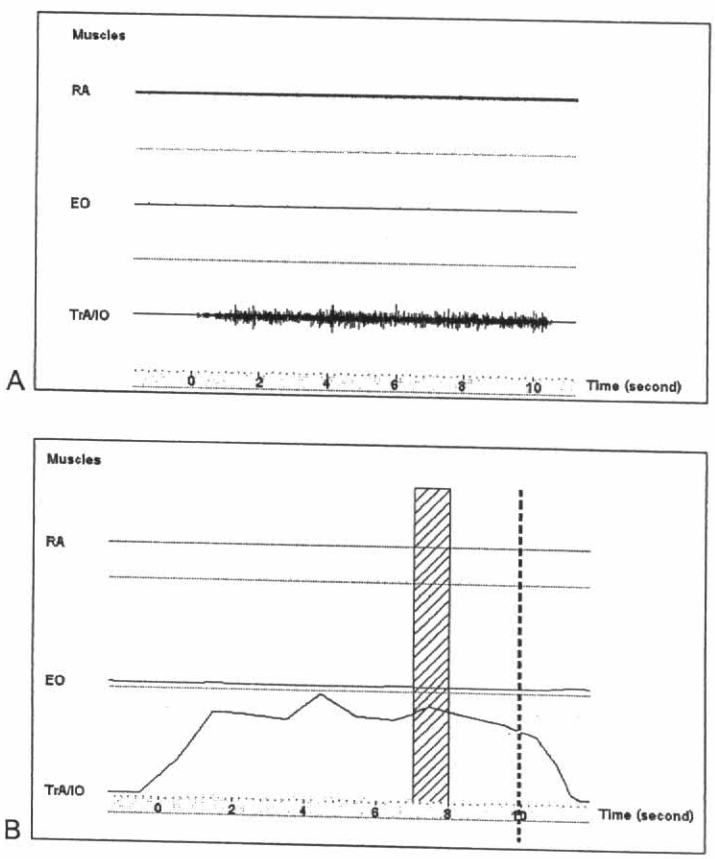


Figure 3.11 Data collection of abdominal hollowing.

A = Raw data of electromyography of rectus abdominis (RA), external abdominal oblique (EO), and transversus abdominis / internal abdominal oblique (TrA/IO). B = Root mean square of electromyography. Dashed line = End of performing and Rectangular bar = Area was collected.

3.7 Statistical analyses

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) for Windows. One-sample Kolmogorov-Smirnov test was used to test whether the EMG activity recorded from the three abdominal muscles in different starting positions was normally distributed. The significant difference level was set at $p < 0.05$. If the data were normally distributed, the two-way repeated measures analysis of variance (ANOVA) was performed. A Tukey's honestly significant difference method was used as a post hoc test to determine which pairwise differences were significant. If the data were not normally distributed, the nonparametric test was considered. For initial assessments of the differences in EMG activity due to muscle or starting position, Friedman two-way ANOVA was performed. This aimed (1) to determine whether there was any significant difference in the EMG activity among the three abdominal muscles in each starting position; and (2) to determine whether there was any significant difference in the EMG activity of each muscle among four different starting positions. Where a significant difference emerged, a multiple comparison procedure by the Wilcoxon signed-ranks test was used to test whether which pairwise differences were significant.

Any differences in the frequencies of inhibition and isolation of three abdominal muscles among four starting position were examined by calculating the percentage of participants who could inhibit activity of the global muscles (RA or EO) and isolate activity of the local muscles (contraction of TrA/IO without activity in RA and EO), respectively. The participants who could keep their RA, EO, or both RA and EO unchanged over the three trials of AH were categorized as 'always' group. The participants who could not keep their RA, EO, or both RA and EO unchanged over the three trials were categorized as 'never' group. The participants who could sometimes keep their RA, EO, or both RA and EO unchanged over the three trials were categorized as 'sometimes' group.