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Can Nipple be used as a Good Indicator of Breast in Breast Motion Research?

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***Abstract*—**There were many studies on how to alleviate breast discomfort by reducing breast motion, in which nipple motion was used to represent breast motion. However, this assumption had not been experimentally validated. The aim of this paper was to experimentally validate if nipple can be used as a good indicator of breast. Seven participants (average of 24.4 years old) were recruited to walk and run on the treadmill at 5km h^{-1} and 10km h^{-1} respectively. Six markers were pasted on their bodies to collect motion data of different parts of breasts. The results of Friedman test combined with the relationship among the five markers on the same breast revealed that nipple could be used as a good indicator of breast. Wilcoxon test showed that there was no significant ($P<0.05$) between left and right nipple's motion, so left nipple and right nipple could both be used to represent breast motion.

***Keywords*—**Bra, breast motion, breast pain, nipple.

I. Introduction

EXERCISE induced breast pain or discomfort has been reported in several surveys [1]-[3], which showed breast pain or discomfort occurred in up to 76% of female athletes as well as 59% of average women. There is no strong support like muscle or bone inside the breast. Although breast skin and Cooper's ligament can support breast to some extent, external support is necessary to prevent stretch on breast tissue or ligament caused by excessive breast motion. Bra was considered as common external support for breast. However, bra cannot provide enough support when they are not well fitted. Unfortunately, 70% to 100% women were estimated to be wearing the wrong size bra [4], which may be a reason for so large a proportion of breast pain or discomfort.

Mason revealed that there was a positive relationship between breast motion and breast pain [3]. It was also found that well-fitted bra could reduce breast motion, and then decreased breast pain or discomfort. Breast motion in different conditions has been paid more and more attention to, especially in recent twenty years [5]. Breast is a three-dimensional object which has surface area and volume. How to choose the points which can represent breast motion was vital to collecting scientific breast motion data.

It was concluded in Mason et al.'s research that nipple movement can best represent breast movement by watching the travel path and amplitude of markers in graphs [3]. Mason et al. thought nipple and inferior point markers' movements followed similar path and had larger amplitude than other markers. Except the researcher's description on the graphs of vertical movement, no graph was shown and no data was given to check whether nipple can be chosen as an appropriate representation of breast. The movement rules of inferior breast points were also unknown, as well as the difference between them.

Besides, the difference between two nipples' movements was little studied in previous research. Breast asymmetry can be used to predict breast cancer [6]-[9]. A positive correlation has been found between breast asymmetry and breast cancer. The relationship between breast asymmetry and fecundity was also studied. Women with more children tended to have more asymmetry [7][10]. Breast asymmetry may be a cue used by males in their choice of fecund and attractive partners [10]. Breast asymmetry was considered as directional with a general clinical impression. However, results of some studies showed that breast asymmetry was fluctuating asymmetry. Since breast asymmetry is common in human, it's surprising that there was rare research on the effect of breast asymmetry on breast motion. In some research it was assumed that there was no difference between left and right nipples' motion [11]. In other research data were averaged between left and right nipples' movement to stand for breast motion [12]. One article [13] studied both left and right nipples' displacement, with the mean of right breast displacement larger than the mean of left one. However no statistic analysis was made between two nipples' motion to check if there was significant difference between them.

It is the breast displacement relative to the body that affects breast discomfort instead of absolute breast displacement. In order to obtain breast displacement relative the body, body's motion needs to be subtracted from absolute breast motion. At the early stage, one reference was used to stand for body's motion. However, one reference cannot capture body's six degree's freedom. Gradually, more than one reference marker was used in some research. Nevertheless, reference markers' positions were very difference from study to study and some reference positions were not anatomical landmarks and difficult to locate [3]-[4][11]-[12][14]-[17]. To compare with the only one related research result [3], one reference marker was used in this research.

The main aims of this paper were (1) to collect motion data of 6 markers and assess if there was significant difference between nipple movement and other markers' movements on the same breast; (2) to assess if there was significant difference between left and right nipples' movement.

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II. Experiment

A. Participants

Seven females who had no history of pregnancy, breast cancer or surgery were recruited from local university, with average age of 24.57 years old (ranging from 22 to 26), average height of 168.5cm (ranging from 156.0 to 172.5cm) and average body mass of 58.5kg (ranging from 51.5 to 61.8kg). Oral consent was received from all participants. The breast size of participants was decided by taking two measurements: under bust girth and full bust girth. Under bust girth was the arc length in level of lowest breast points. Full bust girth was the arc length in level of breast nipples. The measurement method was showed in Fig. 1. Band size was decided by under bust girth, and cup size was decided by the difference between full bust girth and under bust girth. The calculation chart was showed in Table I. According to the calculation method in Table I, seven participants' breast size was showed in Table II. The breast size of all participants was B cup. In order to cater for the requirement of the next experiment, participants were asked to try on fashion bra and sports bra after they were recruited. It was made sure that every participant had a sports bra which fit them very well. Only participants who can find an appropriate sport bra were chosen for the left experiment. For example, female with 70 C breasts cannot find the fitted sports bra. The band of sports bra with size M fits, while the cup is too small. The cup of sports bra with size L fits, while the band is too big. So women with 70C bra size were excluded from the sample.

TABLE I
BRA SIZE CHART AND CALCULATION METHOD

Bra size	70A	70B	80B	85B	90B	95B
Under bust girth (cm)	70	75	80	85	90	95
Full bust girth (cm)	80	87.5	92.5	97.5	102.5	107.5
Bra size	75A	75B	75C	75D	75E	75F
Under bust girth (cm)	75	75	75	75	75	75
Full bust girth (cm)	85	87.5	90	92.5	95	97.5

TABLE II
SEVEN PARTICIPANTS' BREAST SIZE AND CORRESPONDING SPORTS BRA SIZE

Participants	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Breast size	70B	70B	70B	75B	75B	75B	80B
Sports Bra size	M	M	M	L	L	L	XL

B. Experimental Design

All tables and figures you insert in your document are only to help you gauge the size of your paper, for the convenience of the referees, and to make it easy for you to distribute preprints. The breast motion was recorded by Vicon motion capture system when participants were walking or running on the treadmill. Before the real testing, all participants took some time to get familiar with exercise on the treadmill. After that, six pieces of round reflective paper with 1 cm in diameter were attached on participants' bodies (see Fig. 1).

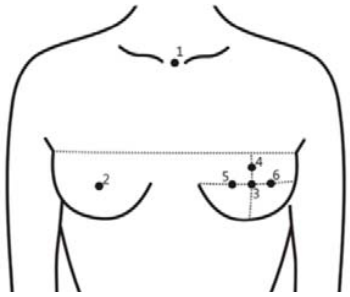

Fig. 1 Six markers' positions in the body

Six pieces of reflective paper were used instead of the original markers of Vicon for they are lighter and had less effect on breast movement. The six pieces of reflective paper had the same function with markers, so for convenience they were also called markers in this paper. Marker 1 was fastened on sternal notch to stand for body motion and the other five markers were sticked on the breast to capture the motion of different parts of breast. Marker 2 and Marker 3 were positioned on the right and left nipples, respectively. Marker 4, 5 and 6 were 5cm from the nipple in sagittal plane and in horizontal plane (Fig. 1).

In order to compare with previous research, sports intensity was set at two levels: walking at 5km h^{-1} and running at 10km h^{-1}. Sixteen Vicon cameras were distributed about 3m around the treadmill and 4m higher than the floor. Data was collected for 10s when participants walked or ran stably on the treadmill. Participants wore their own shorts and unified shoes during the testing.

C. Data Analysis

The coordinates of six markers in breasts were recorded by Vicon motion capture system. Breast motion data were smoothed and filtered at 8 Hz with low pass in Visual 3D software (Version 3.79.0) (see Fig. 2). Movement data of Marker 1 was subtracted from other markers' data to obtain markers' movements relative to the body. Markers' vertical displacement was averaged across five treadmill cycles for each participant. With only one reference marker, the roll and twist of the trunk cannot be eliminated, so only vertical displacement was analyzed in this paper. Normality of all data was tested by Kolmogorov-Smirnow and Shapiro-Wilks tests. Friedman test followed by Wilcoxon test was used to check if there was any significant difference between the markers' movements in the same breast. Wilcoxon test was used to check if there was siginificant difference between left and right nipple markers' motion.

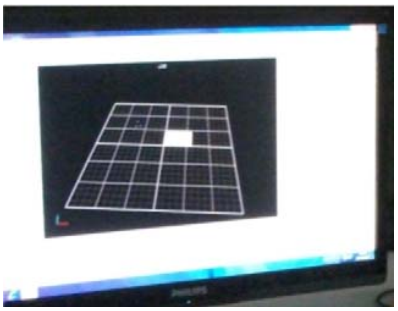

Fig. 2 The interface of Visual 3D software

III. Results and Discussion

A. The Kinematic Data of Five Markers

The means and standard deviations of five markers' vertical movements relative to the trunk were calculated and averaged during five treadmill cycles.

The displacement of all markers during running at 10 km h^{-1} was three to four times as large as their displacement during walking at 5 km h^{-1}. The displacement difference between participants was larger during running than walking (see Fig. 3). There was no big difference between markers and between participants during walking. However, there was a trend of markers' movements in running condition. Markers' movements of participants 7 was largest, followed by participants 4, 5 and 6, and least by participants 1, 2 and 3. Except the data of participant 6 and 7, the displacement difference of markers within one participant was small during walking and running. There was a significant "V" trend in participant 6 and 7's graphs. This may be caused by larger breast sizes of participant 6 and 7, which are 75B and 80B respectively.

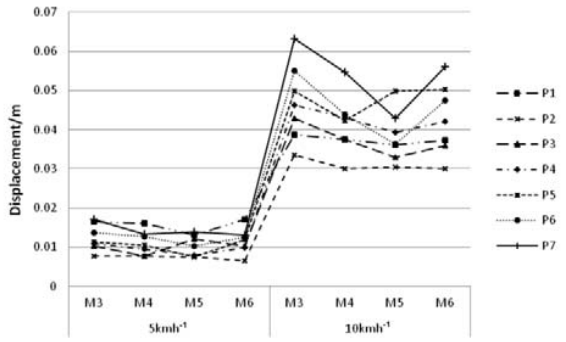

Fig. 3 The vertical displacement of markers in the left breast

In order to understand the relationship among the four markers' movements more clearly, the data of five markers movement was transferred into another presentation. The displacement of left nipple was presumed as 100%, and then other displacement (see Table III).

B. The Difference between Markers' Movements

The sample in this paper indicated slight difference among the movements of markers on the same breast. According to vertical breast displacement, the four markers can be ordered from the largest to the smallest as: M3 (left nipple), M6 (5cm outer nipple), M4 (5cm upper nipple) and M5 (5cm inner nipple). The motion of outer part of breast is larger than upper part and inner part of breast. However, Friedman test showed that there was no significant difference of vertical displacement between the four markers on the left breast during walking (P=0.134), and significant difference was found between them during running (P=0.018).

In order to find out where was the difference between markers' movements on the left breasts during running, Wilcoxon test was used to analyze the data. The analysis result showed that there was significant difference between M3 and M4, M3 and M5, M3 and M6, M5 and M6 (see Table IV). However, there was no significant difference between M4 and M5, M4 and M6.

TABLE III
The Percent of Four Markers' Vertical Displacement in the Left Breast to M3 (Left Nipple)'s Displacement

		M3	M4	M5	M6
5km h^{-1}	P1	100%	97.1%	78.7%	103.4%
	P2	100%	100.8%	97.6%	83.8%
	P3	100%	75.4%	116.8%	99.2%
	P4	100%	86.8%	72.7%	91.7%
	P5	100%	92.7%	65.7%	104.0%
	P6	100%	91.9%	75.1%	91.0%
	P7	100%	78.1%	80.7%	76.4%
	Mean	100%	89.0%	83.9%	92.8%
10km h^{-1}	P1	100%	96.7%	93.2%	96.1%
	P2	100%	89.6%	90.3%	89.4%
	P3	100%	87.4%	77.0%	84.1%
	P4	100%	93.1%	84.7%	90.7%
	P5	100%	84.8%	100.3%	100.8%
	P6	100%	80.0%	66.2%	86.3%
	P7	100%	86.4%	67.9%	88.6%
	Mean	100%	88.3%	82.8%	90.9%

TABLE IV
Test Statistic (P Value) of Breast Displacement of the Four Markers in the Left Breast during Running

		M4	M5	M6
10km h^{-1}	M3	-2.366(0.018)*	-2.197(0.028)*	-2.197(0.028)*
	M4		-1.183(0.237)	-0.507(0.612)
	M5			-2.028(0.043)*

* indicates significant difference where $p < 0.05$.

According to the statistical analysis on markers' movements in the same breast, there was no significant difference during walking and significant difference during running. Nipple motion can represent breast motion during walking but cannot stand for breast motion during running. However, nipple motion was the largest during running. So nipple can still be used as a good indicator in running condition.

The vertical displacements of the left and right nipples were calculated and graphed (see Fig. 4). Wilcoxon test was used to test if there was any significance between left and right nipple's displacement. The result showed that no significant difference was found between left and right nipple's displacement (see Table V) although the sample of the right nipple motion tends to be a little larger than the left one. This result approved that left and right nipple displacement can both be used to calculate the mean of breast displacement. The result was consistent with

the assumption in previous research.

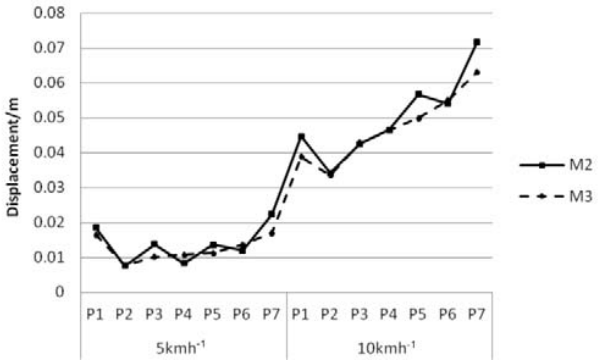

Fig. 4 The Left nipple (M2) and right nipple (M3)'s vertical displacements

TABLE V
MEAN DISPLACEMENT (M) WITH SD OF TWO NIPPLES DURING WALKING AT 5KM/H AND RUNNING AT 10KM/H TOGETHER WITH TEST STATISTIC (P VALUE)

Speed	Right nipple	Left nipple	Z (Sig.)
5km h^{-1}	0.014(±0.005)	0.012 (±0.003)	-1.014(±0.310)
10km h^{-1}	0.050(±0.012)	0.047(±0.010)	-1.352(±0.176)

IV. CONCLUSION

Motion data of seven females, recruited from local university and having no history of pregnancy, breast cancer or surgery, were recorded by Vicon motion capture system. Breast motion data was calculated and analyzed in statistical method to validate the assumptions that nipple motion can represent breast motion and there is no significant different between left nipple and right nipple's motion.

Statistics of markers' displacement certified that nipple displacement was largest in all the four markers during running and there was no significant difference between vertical breast displacements of four markers in the left breast during walking. The result of Wilcoxon test showed there was no significant difference between left and right nipple's displacement. The conclusion can be reached that left nipple or right nipple was a good indicator for breast motion, which was consistent with the result reached by watching in previous research.

It was approved in this study that nipple can be used as a good indicator of breast in vertical direction. However, whether nipple was a good indicator in other two directions was unknown. Since more than one reference positions were used to capture the three-dimensional movement of the body, it is meaningful to test the relationship between nipple motion and other positions' motion in the breast in the other two directions. Besides, the no significant may be resulted from small or median breasts of participants, since the breast sizes of participants were six B cups and one C cup. There was only data about the difference between left and right nipple motion with small breast female, so the trend of right nipple motion being a little larger than the left nipple still needs to be checked by further large sample testing.

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