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Do women with smaller breasts perform better in long distance running?

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Abstract

Literature has established that a range of physiological, biomechanical and training variables influence marathon performance. The influence of anthropometric characteristics has also received attention. However, despite major marathons exceeding 40,000 participants and approximately a third of these runners being female, no data exist on the influence of the breast on running performance. This cross-sectional study aimed to explore the impact of breast mass on marathon finish time. 168 of 321 female marathon runners contacted completed an on-line survey focusing on marathon performance during the 2012 London marathon. Participants were categorised as smaller (<500g, 54%) or larger breasted (>500 g, 46%). Regression analysis identified that 24% of marathon performance variance could be explained by BMI, but breast mass improved the model to explain 28% of performance variation. The model determined that for women with 32/34 or 36/38 underband, each increase in cup size equates to a performance decrement of 4.6 mins or 8.6 mins, equivalent to 34.4 minutes difference between a woman with 36A compared to 36DD breast size. Larger breasted runners had greater BMIs, completed less marathons and had slower marathon finish times (316 ± 48 min) compared to smaller breasted runners (281 ± 51 min). 25% less larger breasted women finished in the fastest quartile. These results suggest that differences in breast mass are an important factor for female athletes and should be considered in future research in this area.

Keywords: breast size; breast mass; performance; running; marathon

Introduction

The popularity of long distance running has increased in recent years with major marathons exceeding 40,000 participants (Burfoot, 2007) and approximately a third of these runners being female (Tunstall-Pedoe, 2004). With these increased participation levels, questions of individual variation in performance arise (Roach, 2012). The ability to predict marathon performance has become a matter of increasing interest.

Literature has established that a range of physiological, biomechanical and training variables influence marathon performance. Optimum maximal oxygen consumption ($\text{VO}_2 \text{ max}$), lactate threshold and running economy are acknowledged as prerequisites for success in long-distance running (Billat, Demarle, Slawinski, Paiva, & Koralsztein, 2001; Joyner & Coyle, 2008; Loftin et al., 2007; Noakes, Myburgh & Schall, 1980). Biomechanical factors such as low vertical oscillation of body centre of mass, more acute knee angles during swing and faster rotation of shoulders in the transverse plane have also been found to be associated with improved running economy (Saunders, Pyne, Telford, & Hawley, 2004). Furthermore, volume and intensity of training are recognised predictors for marathon race time (Bale, Rowell & Colley, 1985; Billat et al., 2001; Christensen & Ruhling, 1983; Yeung, Yeung, & Wong, 2001).

The influence of anthropometric characteristics on marathon performance have also received attention; height (Loftin et al., 2007), body mass index (BMI), body fat percentage (Hagan, Upton, Duncan, & Gettman, 1987), sum of seven skinfold thickness (Hagan, Smith & Gettman, 1981) and calf circumference (Schmid et al.,

2012) have all been found to be related to marathon performance. When examining the relationship between height, BMI, body fat percentage and sum of seven skinfolds with marathon performance in a study of female distance runners ($n = 35$), Hagan et al., (1987) identified that BMI demonstrated the strongest relationship with marathon performance ($r = 0.52$).

Physiological sex differences influence marathon performance and have been of long-standing interest to physiologists (Deaner, 2013). Larger hearts, greater haemoglobin concentration, lower body fat and a greater muscle mass per unit of body mass in males compared to females facilitate larger maximal oxygen consumption and faster marathon times (Cheuvront, Carter, Deruisseau, & Moffatt, 2005; Joyner, 1993, Sparling, 1980). However, there is an obvious anatomical difference between males and females that has received limited attention in relation to long-distance running; the breast.

The breast has limited intrinsic support (Gefen & Dilmoney, 2007) and as a consequence excessive breast movement can occur during physical activity (Page & Steele, 1999; Scurr, White & Hedger, 2009, 2011). The inertia properties of the breast are influenced by the volume and density of the breast (Wood et al., 2012) which differ according to the ratio of fat, glandular and connective tissue (Gefen & Dilmoney, 2007). White, Scurr and Hedger (2010) identified significantly greater vertical breast displacement in larger breasted women (D to DD breast cup size) compared to smaller breasted women (A to C breast cup size), following two-footed vertical counter-movement jumps and agility tasks. Furthermore, examination of three-dimensional breast kinematics of 39 females with breast cup sizes A to JJ

during a two-step jump, identified significant increases in vertical breast displacement as breast cup size increased (Bridgman, Scurr, White, Hedger, & Galbraith, 2010). In a study of breast kinematics of 48 A to G breast cup size women during treadmill running, significant increases in breast displacement, velocity and acceleration were also identified with increases in breast cup size (Wood et al., 2012). These findings indicate that in a range of activities, including running, larger breasts exhibit greater movement compared to smaller breasts.

Excessive breast motion can result in a number of negative consequences including breast pain, potential breast sag, and embarrassment (Mason, Page & Fallon, 1999; Page & Steele, 1999). Alteration of kinematic and kinetic running profiles have also been observed in different breast support conditions (Shivitz, 2001; White, Scurr & Smith, 2009) which may have implications for performance. A well-fitting sports bra has been reported to effectively reduce breast motion (Page & Steele, 1999; Scurr et al, 2009, 2011) and is an important consideration for females participating in physical activity, both recreationally and competitively.

Only one study has considered the influence of the breast during long-distance running. In a survey of 1285 female marathon runners Brown, White, Brasher and Scurr (2014a) identified that a third of marathon runners experienced breast pain, a phenomenon that increased with breast cup size. Furthermore, the authors reported a link between exercise participation and breast pain, with 17% of symptomatic participants reporting that breast pain impacted their exercise behaviour. Whilst this study identified an influence of breast pain on exercise behaviour, this study did not consider the subsequent influence of the breast on marathon performance. Empirical

research has not firmly established if breast size is related to body size and composition (Byrne & Spornak, 2005). Beijerinck, van Noord, Kemmeren, and Seidell (1995) and Benditte-Klepetko et al. (2007) reported a relationship between body mass and breast size, with Hasenburg, Grothey, Jaspers, Gitsch, and Spatling (2000) reporting a relationship between BMI and breast size (Hasenburg et al., 2000). However, in a sample of 973 women awaiting breast augmentation Vandepuit and Neliessen (2002) found no correlation between breast mass and breast size. Additionally, Katch et al., (1980) reported that breast mass accounts for no more than 4.4% of total body fat mass (Katch et al., 1980). Furthermore, in a study investigating the heritability of breast size, only one third of the genetic variance in breast size was common with genes influencing body mass index (Wade, Zhu & Martin, 2010). Brown et al., (2012) identified that BMI accounted for 43% of the variance in breast mass, indicating a large proportion of the variance in breast size is as yet unaccountable, and may influence performance.

The marathon attracts a range of participants from novice runners who have never previously participated in a running event, to experienced runners who regularly enter and complete marathons (Jaworski, 2005), thus providing an interesting model to analyse performance trends of athletes. To date, no data exist on the influence of the breast on running performance. Accordingly, this cross-sectional study was conducted as an initial exploration in this area. The study aimed to identify whether breast mass can predict marathon performance and determine if there are differences in marathon finish time between smaller and larger breasted females. It was hypothesised that as BMI has demonstrated the strongest relationship to marathon finish time in previous literature, BMI would act as a significant predictor of

marathon performance, but that the addition of breast mass would increase the predictive capability of the model. Secondly, it was hypothesised that smaller breasted women would achieve significantly faster marathon finish times compared to larger breasted women.

Methods

Following full institutional ethical approval an e-mail link to an on-line survey was sent to 321 females who had participated in a previous survey of marathon runners' breast health issues during training for the 2012 London marathon (Brown et al., 2014a; Brown, White, Brasher & Scurr, 2014b) and who gave consent to participate in a follow up survey. Of 321 participants contacted, 185 responses were received (58% response rate). The survey, including a standard statement of consent, was administered via Survey Monkey website and was only available in English. The survey was conducted immediately following the 2012 London marathon (22 April) and remained live for three weeks. All data were anonymous.

The survey consisted of multiple choice, Likert scale, and free-text response questions, and was designed to take no more than 10 min to complete. Initial survey questions identified the number of marathons participants had previously completed (none, 1 to 2, 3 to 4, ≥ 5), previous running experience (years) and their 2012 London Marathon finish time (min). Respondents were also asked to provide demographic data including age (years), height (m), body mass (kg), bra size (under band size and cup size) and menopausal status (pre-, mid- or post-menopausal).

Data handling

Responses were automatically downloaded into Microsoft Excel (2010) from the on-line survey. Of the 185 responses received, 11 data sets were excluded due to blank ($n=5$) or incomplete ($n=7$) responses, and a further 3 surveys were excluded due to not participating in the 2012 London Marathon, resulting in 168 completed surveys. BMI was calculated (kg/m^2) and using self-reported breast size, breast mass (g) was estimated using the breast tissue resection weights presented by Turner and Dujon (2005). These include estimates of 115 g per cup size for 32 to 34 inch underbands and 215 g per cup size for underbands of 36 to 38 inches. Estimates of breast mass for 28 and 30 inch under bands were not reported by Turner and Dujon (2005), therefore, to estimate breast mass for these under band sizes, a cross-grading system was applied whereby the participants appropriate cup size (one smaller) for a 32 inch underband was used to estimate breast mass; a method previously used by Brown et al (2012). For comparison, participants with a breast mass <500 g or >500 g were defined as smaller (54%, $n = 90$), or larger breasted (46%, $n = 78$), respectively (Gefen & Dilmoney, 2007).

Data analysis

Demographics and running experience

Participants' demographics and running experience were summarised using descriptive measures. Continuous variables were expressed as a mean (standard deviation) and categorical variables were expressed as a percentage. Inferential analyses were performed using Predictive Analytic Software statistics computer package with statistical significance set at $P < .05$. BMI and running experience (years) were not normally distributed, as assessed by Shapiro-Wilk's test ($P < .05$).

Therefore non-parametric differences in these continuous variables between smaller and larger breasted females were assessed using Mann Whitney U tests. All categorical variables were assessed using chi-squared tests. For large cross-tabulations, if the overall chi-squared was significant, standardised adjusted residuals for the cell percentage of each subgroup were examined to determine which cell differences contributed to the chi-squared test results. An adjusted residual score greater than 1.96 for a given subgroup percentage indicated that the subgroup differed significantly ($P < .05$) from the overall group percentage (Field, 2013).

The breast and marathon performance

Stepwise multiple regression analysis was conducted to evaluate the predictive value of BMI and breast mass in relation to marathon finish time. Marathon finish times were normally distributed as assessed by Shapiro-Wilk's test ($P > .05$); therefore differences in marathon finish times between smaller and larger breasted females were assessed using an independent t -test. Additionally, marathon finish time was categorised into quartiles and chi-squared analysis performed to determine whether quartile groups differed between smaller and larger breasted females.

Results

Demographics and running experience

Participants had a mean (standard deviation) self-reported body mass of 63.3 (9.0) kg, stature 1.65 (0.6) m, and BMI of 23.1 (2.1) kg/m² (Table 1). Larger breasted women were significantly heavier ($Z = -6.711$, $P < .05$) and had significantly higher BMIs ($Z = -6.367$, $P < .05$) compared to smaller breasted women. The mode age

bracket was 30 to 39 years, three quarters (75%) of women were pre-menopausal and over half (52%) were nulliparous. Self-reported breast cup size ranged from an AA cup to a GG cup with underband size ranging from 28 to 38 inches (mode bra size 34B, $n=28$). The frequency distribution of breast mass was positively skewed (Figure 1), ranging from 115 g to 2,150 g with a mode breast mass of 230 g ($n = 36$).

A significantly higher proportion of smaller breasted participants reported participating in ≥ 3 previous marathons compared to larger breast participants ($X^2 = 10.978$, $P < .05$), however there was no significant difference in previous years running experience between smaller and larger breasted participants ($Z = -1.238$, $P > .05$).

The breast and marathon performance

Stepwise multiple regression analysis was used to test the hypothesis that BMI and breast mass could predict marathon finish times (Table 2). The first model incorporated BMI only and accounted for 24% of the variance observed in marathon finish times ($R^2 = 0.239$) and was significant ($F = 51.874$, $P < .05$). The second model included BMI and breast mass and was also significant ($F = 31.788$, $P < .05$), increasing the explained variance significantly to 28% (R^2 change = 0.040, $P < 0.05$).

Unstandardised β coefficients in the regression model (Equation (1)) indicate that a female with a BMI of 27 kg/m² and a breast mass of 230 g (equivalent to a 34B), would have a marathon finish time (t) of 310.4 min. With other variables held constant, marathon finish time increases by 4.6 min for each increase in breast cup size for women with an underband of 32 or 34 inches (based on 115 g per cup size),

and by 8.6 min for each increase in breast cup size for women with a 36 or 38 underband (based on 215 g per cup size) (Turner & Dujon, 2005).

Equation 1
$$t = 135.3 + 6.144 \times BMI + 0.04 \times breast\ mass \quad (1)$$

London Marathon 2012 finish times were significantly slower in larger breasted runners (316 ± 48 min) compared to smaller breasted runners (281 ± 51 min) ($t = -4.753$, $P < .05$). Having categorised marathon finish times in to quartiles, chi-squared analysis revealed that significantly less larger breasted women finished in the 1st quartile compared to smaller breasted women (12% and 37%, respectively) and significantly more larger breasted women finished in the last quartile (37% and 14%, respectively) ($X^2 = 19.423$, $P < .05$) (Table 3).

Discussion

This is the first study to investigate the influence of the breast on marathon running performance. Traditionally, studies investigating the predictive capability of anthropometric parameters on marathon performance have focused on body size and adiposity. Research evidence suggests that breast mass accounts for only approximately 4% of total body fat weight (Katch et al., 1980). The current study identified that breast mass, which has not been considered in existing literature, explained an additional 4% of the variance observed in marathon finish times when added to a predictive model that included BMI, thus accepting hypothesis one. These results provide support for the consideration of breast mass in addition to overall body size when predicting marathon performance.

The data in the current study revealed that for women with an underband of 32 or 34 inches, a one breast cup size increase (equivalent to 115 g) can result in a 4.6 min increase in marathon finish time. When comparing the 50th percentile marathon finish time of the current cohort (296 min) to the finish times of females who completed the 2014 London marathon (Virgin London Marathon, 2104), a 4.6 min increase would result in finishing the marathon in 10522 place compared to 7532 place, a difference of 2990 positions. For women with a 36 or 38 inch underband, up to a 25 min difference in marathon finish time could be expected between a woman with a C breast cup size and an E breast cup size (a difference of 3 breast size cups).

The results identified that smaller breasted runners achieved significantly faster marathon finish times than larger breasted runners, with more than twice as many larger breasted runners finishing in the slowest quartile compared to smaller breasted runners, thus accepting hypothesis two. Previous research has established that larger breasted runners experience greater breast displacement (White, Scurr & Hedger, 2010; Wood et al., 2012). It has also been suggested that females may adapt running mechanics in an attempt to reduce breast motion and that this is likely to affect kinetic characteristics and performance (Shivitz, 2001; White et al., 2009). This may provide a potential explanation for the slower marathon finish times observed in larger breasted runners. Smaller breasted participants in the current study also had significantly lower BMIs and had completed more marathons compared to larger breasted participants. These findings are in agreement with Brown et al. (2012) who identified significant anthropometric differences between smaller and larger breasted women, in addition to identifying that BMI accounted for 43% of the variance in breast mass. This leads to another potential explanation that

superior running performance may be a result of increased training and subsequent body size reduction, leading to a reduction in breast size.

This study has some limitations that may have influenced the results. Firstly, data came from a cross sectional survey, therefore it is not possible to discern causal relationships. Secondly, it is acknowledged that there are a wide range of other known factors that are associated with marathon performance such as physiological and training variables that were not investigated in the current study. We focused this investigation specifically on the breast which previous literature has not considered; therefore these results are the first step towards determining the impact of the breast on marathon performance. For future research the collection of other known predictors of marathon performance, including physiological and training variables, could be examined in conjunction with breast mass, to fully understand the value of breast mass as a predictor of marathon finish times. Another potential limitation of the current study is the ability to generalise the findings to other female marathon populations, although the sample demonstrated a range of ages, anthropometric variables, running experience and marathon finish times. In that sense, the cohort is representative of the broad spectrum of females that participate in marathons.

Conclusion

In summary, withstanding the cautions outlined above, the regression model established in this study identified that 24% of the variance in marathon performance could be explained by BMI, but the addition of breast mass increased the predictive capabilities of the model to explain 28% of the performance variation. The regression

model determined that (with other variables held constant) for women with 32/34 underband size each increase in cup size equates to a performance decrement of 4.6 min, or 8.6 min for 36/38 underband size. This suggests that there would be a 34.4 min differential between a women with 36A compared to 36DD breast size. The present study also reports that compared to smaller breast runners, the larger breasted runners in this study had a slower marathon time, were heavier, had a greater BMI and had completed less marathons previously. Twenty five percent less larger breasted women finished in the fastest quartile of marathon finish times. These results suggest that consideration of differences in breast size/mass are an important factor in future research in this area.

References

- Bale, P., Rowell, S., & Colley, E. (1985). Anthropometric and training characteristics of female marathon runners as determinants of distance running performance. *Journal of Sports Sciences*, 3, 115-26.
- Beijerinck, D., van Noord, P. A., Kemmeren, J. M., & Seidell, J. C. (1995). Breast size as a determinant of breast cancer. *International Journal of Obesity Related Metabolic Disorders*, 19, 202-205.
- Benditte-Klepetko, H., Leisser V, Paternostro-Sluga, T., Rakos, M., Trattinig, S., Helbich, T., Schemper, M., & Deutinger, M. (2007). Hypertrophy of the breast: a problem of beauty or health? *Journal of Womens Health*, 16(7), 1062-1069.

Billat, V. L., Demarle. A., Slawinski, J., Paiva, M., & Koralsztein, J. P. (2001). Physical and training characteristics of top-class marathon runners. *Medicine and Science in Sports and Exercise*, 33, 2089-2097.

Bridgman, C., Scurr, J., White, J., Hedger, W., & Galbraith, H. (2010). Three-dimensional kinematics of the breast during a two-step star jump. *Journal of Applied Biomechanics*, 26(4), 465-472.

Brown, N., White, J., Brasher, A., & Scurr. J. (2014a). The experience of breast pain (mastalgia) in female runners of the 2012 London Marathon and its effect on exercise behaviour. *British Journal of Sports Medicine*, 48, 320-325.

Brown N, White J, Brasher A, Scurr J. (2014b). An investigation into breast support and sports bra use in female runners of the 2012 London Marathon. *Journal of Sports Science*, 32(9):801-809.

Brown, N., White, J., Milligan, A., Risius, D., Ayres, B., Hedger, W., & Scurr, J. (2012). The relationship between breast size and anthropometric characteristics. *American Journal of Human Biology*, 24(2), 158–164.

Burfoot, A. (2007). The history of the marathon. *Sports Medicine*, 37, 284–287

Byrne, C., & Spernak, S. (2005). What is breast density? *Breast Cancer Online*, 8(10), 1-7.

Cheuvront, S. N., Carter, R., Deruisseau, K. C., & Moffatt, R. J. (2005). Running performance differences between men and women: an update. *Sports Medicine*, 35, 1017–1024.

Christensen, C. L., & Ruhling, R. O. (1983). Physical characteristics of novice and experienced women marathon runners. *British Journal of Sports Medicine*, 17, 166-71.

Deaner, R. O. (2013). Physiology does not explain all sex differences in running performance. *Medicine and Science in Sports and Exercise*, 45(1), 146-147.

Field, A. (2013). *Discovering Statistics using IBM SPSS Statistics*. (4th ed). London: SAGE.

Gefen, A., & Dilmoney, B. (2007). Mechanics of the normal woman's breast. *Technology Health Care*, 15, 259–71.

Hagan, R. D., Smith, M. G., & Gettman, L. R. (1981). Marathon performance in relation to maximal aerobic power and training indices. *Medicine and Science in Sports and Exercise*, 13, 185–189.

Hagan, R. D., Upton, S. J., Duncan, J. J., & Gettman, L. R. (1987). Marathon performance in relation to maximal aerobic power and training indices in female distance runners. *British Journal of Sports Medicine*, 21, 3–7.

Hasenburg, A., Grothey, A., Jaspers, V., Gitsch, G. & Spatling, L. (2000). Breast size as risk factor for tumor size at diagnosis. *Anticancer Research*, 20(3B), 2041-2044.

Jaworski, C. A. (2005). Medical concerns of marathons. *Current Sports Medicine Reports*, 4, 137-143.

Joyner, M. J. (1993). Physiological limiting factors and distance running: influence of gender and age on record performances. *Exercise Sports Science Reviews*, 21, 103–33

Joyner, M. J., & Coyle, E. F. (2008). Endurance exercise performance: the physiology of champions. *Journal of Physiology*, 586, 35–44.

Katch, V. L, Campaigne, B., Freedson, P., Sady, S., Katch, F. I., & Behnke, A. (1980). Contribution of breast volume and weight to body fat distribution in females. *American Journal of Physical Anthropology*, 53, 93-100.

Loftin, M., Sothorn, M., Koss, C., Tuuri, G., Vanvraencken, C., Kontos, A., & Bonis, M. (2007). Energy expenditure and influence of physiologic factors during marathon running. *Journal of Strength & Conditioning Research*, 21, 1188-1191.

Mason, B. R., Page, K., & Fallon, K. (1999). An analysis of movement and discomfort of the females breast during exercise and the effects of breasts support in three cases. *Journal of Science and Medicine in Sport*, 2, 134-144.

Noakes, T. D., Myburgh, K.H., & Schall, R. (1980). Peak treadmill running during the VO₂max test predicts running performance. *Journal of Sports Science*, 8, 35-45.

Page, K. A., & Steele, J. R. (1999). Breast motion and sports brassiere design. Implications for future research. *Sports Medicine*, 27(4), 205–11.

Roach, L. E. (2012). *Thermoregulation and marathon performance: relationships of predictability of marathon performance, ambient weather conditions, BSA:MT, BSA:ML, percent body fat, and aerobic fitness*. (Unpublished master's thesis). University of Michigan, Michigan.

Saunders, P. U., Pyne, D. B., Telford, R. D., & Hawley, J. A. (2004). Factors affecting running economy in trained distance runners. *Sports Medicine*, 34(7), 465-485.

Schmid, W., Knechtle, B., Knechtle, P., Barandun, U., Rüst, C. A., Rosemann, T., & Lepers, R. (2012). Predictor variables for marathon race time in recreational female runners. *Asian Journal of Sports Medicine*, 3, 90–98.

Scurr, J., White, J., & Hedger, W. (2009). Breast displacement in three dimensions during the walking and running gait cycle. *Journal of Applied Biomechanics*, 25(4), 322-329.

Scurr, J., White, J., & Hedger, W. (2011). Supported and unsupported breast displacement in three dimensions across treadmill activity levels. *Journal of Sports Science, 29*, 55–61.

Shivitz, N. L. (2001). *Adaptation of vertical ground reaction force due to changes in breast support in running*. (Unpublished master's thesis). Oregon State University, Oregon.

Sparling, P. B. (1980). A meta-analysis of studies comparing maximal oxygen uptake in men and women. *Research Quarterly for Exercise and Sport, 51*, 542–52.

Tunstall-Pedoe, D. S. (2004). Human capability and vulnerability in mass marathon running. In E. G. L. Soulsby & J. F. Wade (Eds.), *Proceedings of a workshop on sporting injuries in horses and man: A comparative approach, Lexington, USA* (pp. 75-79). Newmarket, UK: R & W Communications.

Turner, A.J., & Dujon, D.G. (2005). Predicting cup size after reduction mammoplasty. *British Journal of Plastic Surgery, 58*, 290-298.

Vandeput, J. J. & Nelissen, M. (2002). Considerations on anthropometric measurements of the female breast. *Aesthetic Plastic Surgery, 26*(5), 348-355.

Virgin London Marathon. (2014). 2014 Virgin Money London Marathon Media Guide. Retrieved from <http://static.london-marathon.co.uk/downloads/pdf/Media-Guide-14-FINAL-lowres.pdf>

Wade, T. D., Zhu, G., Martin, N. G. (2010). Body mass index and breast size in women: same or different genes? *Twin Research & Human Genetics*, 13(5), 450-454.

White, J., Scurr, J., & Hedger, W. (2010). Three-dimensional breast displacement and breast comfort in small and large-breasted women during jumping and agility tasks. In F. Korkusuz, H. Ertan, & E. Tsolakidis (Eds.), *Proceedings of the 15th Annual Congress of the ECSS* (pp. 138), Antalya: ECSS.

White, J., Scurr, J., & Smith, N. (2009). The effect of breast support on kinetics during over-ground running performance. *Ergonomics*, 52(4), 492-498.

Wood, L. E., White, J. Milligan, A., Ayres, B., Hedger, W., & Scurr, J. (2012). Predictors of three-dimensional breast kinematics during bare-breasted running. *Medicine and Science in Sports and Exercise*, 44(7), 1351-1357.

Yeung, S. S., Yeung, E. W., & Wong, T. W. (2001). Marathon finishers and non-finishers characteristics. A preamble to success. *Journal of Sports Medicine and Physical Fitness*, 41, 170-6.

Table 1. Comparison of age, anthropometric variables and running experience between smaller breasted (n = 90) and larger breasted (n = 78) runners who completed the London Marathon 2012.

	Mean (SD) (unless otherwise stated)			Statistical test result
	All participants	Smaller breasted	Larger breasted	
Age (years)				$\chi^2 = 5.302$
18 to 29	18%	20%	15%	
30 to 39	34%	38%	31%	
40 to 49	29%	21%	37%	
> 50	19%	21%	17%	
BMI (kg/m²)	23.1 (2.9)	21.9 (2.3)	24.5 (2.9)	$Z = -6.367^*$
Menopausal status				$\chi^2 = 0.199$
Pre	75%	73%	76%	
Mid	16%	17%	15%	
Post	10%	10%	9%	
Given Birth				$\chi^2 = 5.302$
Yes	48%	43%	54%	
No	52%	57%	65%	
Previous marathons completed				$\chi^2 = 10.978^*$
None	51%	46%	56%	
1 to 2	25%	20%	31%	
3 to 4	11%	<u>16%</u>	5%	
≥ 5	14%	<u>18%</u>	8%	
Previous running experience (years)	7.5 (7.0)	8.4 (8.0)	6.5 (5.7)	$Z = -1.238$

Note: Underlined cells show those with significant adjusted standardised residuals

*significant difference between smaller and larger breasted participants at .05 level

Table 2: Regression analysis for BMI and breast mass predicting marathon finish times (t), displaying regression coefficients and model fit statistics for each model ($n = 168$).

Variable	R	R^2_{adj}	Unstandardised coefficient β	Standardised coefficient β	t
Model 1					
Constant	-	-	89.541 (29.166)		3.070*
and BMI	0.489*	0.239*	9.006 (1.250)	0.489	7.202*
Model 2					
Constant	-	-	135.268 (32.239)		4.196*
and BMI			6.144 (1.545)	0.334	3.977*
and breast mass	0.529*	0.279*	0.040 (0.013)	0.254	3.024*

Note: Estimated coefficients are given with standard errors in parentheses

*Significance at .05 level

Table 3. Percentage of smaller and larger breasted women within marathon finish time quartiles (n = 168).

Marathon finish time quartile (range)	Smaller breasted (%)	Larger breasted (%)
1 st (< 262 min)	37	<u>12</u>
2 nd (263 – 296 min)	23	27
3 rd (297 – 330 min)	26	24
4 th (>331 min)	14	<u>37</u>
Statistical test result	$\chi^2 = 19.423^*$	

Note: Underlined cells show those with significant adjusted standardised residuals

*significant difference between smaller and larger breasted participants at .05 level

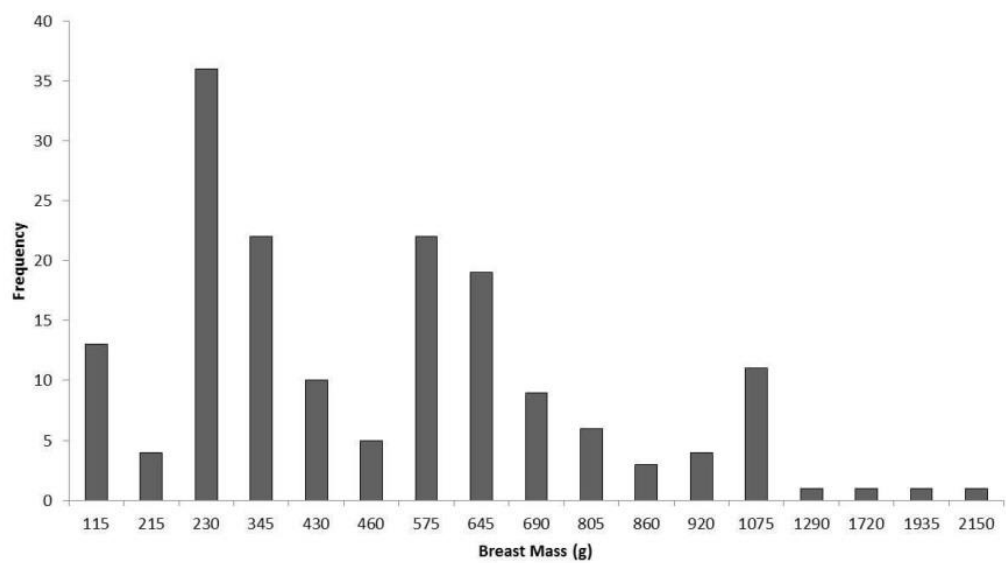


Figure 1. Distribution of participants breast mass (n = 168)