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Could Differences in Muscle Group Strength Explain Observed Differences in Child Carrying Positions?

Laura Stearns
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Abstract

Despite the frequency and necessity of child-carrying by adults, very little research has focused on the energetic costs and behavioral patterns associated with this activity. This study explores differences in physical capacity between females and males as a possible explanation for the observation that men are more commonly seen carrying children on their shoulders, while women tend to carry toddler-sized children on their hips. To address this issue, I measured the one-repetition maximum (1RM) of four large muscle groups in 5 female and 4 male participants (age 18-45 y). The 1RM procedure determines the largest mass a person can lift one time with correct form. Because the participants carried a toddler-sized manikin (11 kg) either on their shoulders or their hips, I chose four muscle groups related to these tasks: arm curl, bent-over row, leg press, and shoulder press. Males had higher 1RMs for all of the muscle groups than females (p values between 0.006 and 0.06). For the females, the toddler mass was 91%, 54%, 46%, and 11% of their 1RM for arm curls, bent-over row, shoulder press, and leg press, respectively, while for the males 50%, 31%, 16%, and 4%. The greater strength of their shoulder muscle group gives men, in general, a greater ability to lift children onto their shoulders. As demonstrated by the results hip-carrying for women might be a more manageable alternative, since a toddler would be near the limit of their single-arm curl strength. These results have implications regarding our predictions about child-carrying interactions in populations of contemporary humans as well as in groups of the earliest known humans.

Introduction

As obligate bipeds, *Homo sapiens* parents have always needed to carry their offspring. In the earliest stages of life humans, are unable to walk on their own.¹ Thus, the act of carrying children is present in all cultures across the world. People carry children in different positions of comfort and use different tools, such as slings, to aid in the carrying process.²

Two of the most common ways of carrying a child, without a tool, are on the hip and on the shoulders. These carrying behaviors are observed in both men and women. To date, the reasons for why people choose to carry a child in a specific position have not been significantly researched. According to Wall-Scheffler *et al.* (2007), the use of tools, like slings, to help hold children have been shown to be metabolically preferred.² The tools help by taking away some of the muscular strain of the excess weight that is placed on the body by the child. The
individuals need to have a certain amount of muscle strength to lift up and hold a child in a
certain position. Wall-Scheffler et al. (2007) found that the sling tool was 16% less energetically
costly than carrying a child on the hip without a tool.

There are the anatomical differences between men and women. Men have relatively
narrower hips and therefore have less of a “shelf” for a child to sit on when carrying on the hip.
The women have a relatively wider hip due to the process of child birth they have more of a
“shelf.” Men also tend to have wider shoulders than women and thus may have more stability
when carrying a child on their shoulders. Physical differences could lead to an explanation for
the variations of carrying behaviors.

Further, muscle strength could be a factor in carrying efficiency. There are two ways to
test muscle strength. One way is absolute strength and the other is relative strength, which is
the strength a person has relative to their body size. Absolute strength is the amount that one
is able to lift and does not consider the size of the person. Generally, determination of absolute
muscle strength is done by testing weightlifting capacities with a one-repetition maximum
(1RM). Testing a 1RM can be difficult for subjects and has a possibility of causing muscle
damage. There are many prediction equations in place to predict a 1RM for an individual
based on a submaximal weight and the amount of repetitions that the individual can complete
correctly. One of the equations used to predict a 1RM is the Brzycki’s equation (equation 1).

\[
\text{wt}/(1.0278-(0.0278*\text{rep}))
\]  

(Equation 1)

This equation does not change based on the sex, age of the population, or the exercise that is
being performed. There are differences in strength among all individuals. There are many
submaximal prediction equations that have been published, but many include different factors for the muscle group tested, age, and/or gender of the person completing the task.\textsuperscript{4,5,6}

To carry a child absolute strength is required in many muscle groups. To lift a child onto one’s shoulders the muscles in the back and arms are used. These muscles need to be able to support and lift the weight of the child in order for the individual to place the child onto one’s shoulders. For someone to hold a child on their hip, their arms need to have enough strength to hold the child in place. Once the person is holding the child the back and abdominal muscles are then used to keep the individual upright. The final group of muscles that are used are the legs. The legs need to be strong enough to both hold up the child and to walk at the range of speeds required in daily life.

Currently, there are no studies stating that men are more likely to carry children on their shoulders than women, or that women are more likely to carry a child on their hips. The only information that can be obtained to quantify this observation is from blogs and short surveys. There are two common topics among these blogs. The first is that women had concerns about “men carrying children on their shoulders,” because many women would not trust themselves carrying children on their own shoulders.\textsuperscript{8,9} The second theme is that while both sexes will carry children on their shoulders, they are doing this less because of the development of new tools like slings. Women often do not carry children on their shoulders. These common themes give reasons for why men are more likely to carry children on their shoulders than women.

The objective of the present study was to determine the differences in strength in men and women while carrying children. The differences in strength may explain differences in child
carrying patterns. People are going to choose a position of comfort or economy when carrying offspring. The ability of a person to lift and hold a set amount of weight is limited by the strength of certain muscle groups. These differences in strength may then explain discrepancies in child carrying patterns. The strength limitations may be the reason that women are probably less likely to carry a child on their shoulders than are men.

**Methods**

This thesis was one component of a larger human metabolic study. The larger study included twelve subjects (6 male and 6 female), young to middle-aged adults (19-45), who were non-smokers and in good physical condition. The subjects were asked to walk around a gym and on a treadmill at four different speeds: “slow walk”, “walk-all-day”, “brisk walk”, and “fast walk,” while carrying an 11-kg toddler model around their waist, on their shoulders, or an 11-kg weight belt worn around their waist. During the test all of the subjects were wearing a COSMED portable metabolic device. The COSMED K4B2 measured the O$_2$ consumption and CO$_2$ produced with each breath in order to calculate rate of energy use.

There were a total of twelve trials per day on each of the four day periods that the subjects participated. The subjects were tested in the gym for two of the days and this looked at their preferred speed when they were allowed to free walk with the given speed directive. The other two days were completed on a treadmill. At the first treadmill session, four speed directives were given and the subject picked a speed that felt like the given directive. The order of completion for each carrying position, walking speed, and location were chosen at random.

The subjects completed each walking speed in the gym and on the treadmill while carrying an 11-kg toddler model on their hip or on their shoulders. The control condition was
when the participants wore an 11-kg weight belt worn around their waist. In combination with
the different speed directives, each participant underwent a total of 12 conditions both days in
the gym, and both days on the treadmill. Overall, the subjects completed a total of 48 trials
each. All of the subjects were videotaped for all of the trial days. The camera was at a side
view for one of the treadmill days and from behind the second day. In the gym the camera was
at a side view for both of the trials.

A further measurement looked at limb segment composition. To determine the
composition all of the subjects underwent a dual-energy x-ray absorptimetry (DEXA) scan. This is
a scan that is often used to determine bone density and body composition. The dual-energy x-
ray is able to determine the different densities of body tissue. There are three main categories
of tissue that the DEXA can differentiate between. In order of least dense to most dense are fat,
lean muscle, and bone. In general, the more muscle tissue that is present, the stronger the
muscle group action is that can be achieved. The body was divided into nine different body
segments after the DEXA scan, in order to represent the muscle groups that would be used in
each of the strength exercises.

Eleven of the subjects (5 male and 6 female) consented to be tested for their one-
repetition maximum and to have the Brzyki’s equation used to predict their 1RM (see equation
1) for four different lifts: an arm curl (right and left), bent-over row (right and left), shoulder
press, and a leg press. The arm curl tests the strength of the muscles that are used when
carrying a toddler on the hip. Differences in strength between the right and left arms may be
an explanation of the preferred side for that person to carry the toddler model. The bent-over
row was used to test the group of back muscles used to keep a person erect while carrying a
toddler on either their shoulders or hip. Only four of the 5 consenting male subjects completed
this exercise, because the 5th subject’s 1RM was not able to be obtained with equipment
available. The shoulder press was chosen because it tests the strength of the back and arm
muscles used to place a toddler on to the shoulders. Those muscles need to be strong enough
to lift the toddler if the adult chooses to carry them on their shoulders. The leg press tests the
strength of the muscles used in walking. A toddler is an increased amount of weight to walk
with and thus may limit the ability to walk at a normal pace.

All of the subjects were brought into the Saint Catherine University weight room. For
each weight training exercise the subjects started with the lightest possible weight and did 10
repetitions. The subjects were then asked if they knew how much weight they were used to
lifting. If they did not know a weight amount was chosen based on their physical size. The
subjects were asked to do as many repetitions as possible. If they were able to complete 10
repetitions they were told to stop and the weight was increased. The weight was increased at
different increments based on the ease of completion and the exercise that was being
completed. Once the subject reached a weight that the subject was able to do between 2-10
repetitions the weight and number of repetitions were plugged into equation 1. The result
from this equation was the predicted 1RM for that muscle group and subject. The 1RM was
determined when the subject reached a point of fatigue. A point of fatigue is when the subject
tried to complete a repetition, but they were unable to do so with the correct biomechanics.
Once the subject was only able to do one repetition correctly this was considered their actual
one repetition maximum.
**Results**

**Comparison of Actual and Predicted 1RM**

Figure 1 (A-F) shows all of the results for the Bryski’s equation. The first methodological objective was to determine the reliability of the Bryski’s equation by comparing the predicted 1RM to the actual 1RM (equation 1). All of the results for the Bryski’s equation are shown in Figure 1. It should be noted that on all of the graphs the male subject’s data are in blue and the female subject’s data are in purple. Figure 1 (A-F) shows the results for the submaximal prediction equation. The dark black line is the line of best fit for all of the subjects. The colors differentiate the values between the men and women. The $R^2$ values for the regression lines between the actual 1RM and the predicted 1RM range from 0.985 to 0.9976 for all muscle exercises. This shows a strong correlation between the actual 1RM and the predicted 1RM. The green dashed line on the figure represents the “identity”. The identity would mean that the Bryski’s equation perfectly predicted the 1RM. Overall, the predicted 1RM was slightly lower than the actual 1RM. However, but due to the high $R^2$ values show that the prediction was consistently low to the same extent for all subjects. The equation worked similarly for all muscle groups and both sexes.
Figure 1(A-F): Comparison of the actual one-repetition maximum (kg) to the predicted value using the Brzyki’s equation from submaximal weights (kg) for all muscle groups and sides of the body.
Comparison of Actual 1RM to Muscle Mass

Figure 2(A-D) shows the comparison between the results of the lean muscle mass determined by the DEXA scan and the actual 1RM. The body segment that was chosen for both the arm curl and the shoulder press was the entire upper extremity. The right side of the body was the only one available from the DEXA scan. It is assumed that the right and left side of the body have similar body composition. This is supported by matching right and left side also had the same 1RM for seven out of the eleven subjects in the bent-over row and the arm curl was the same for all eleven subjects having the same bilateral 1RM for the arm curl. The bent-over row 1RM was compared to the lean muscle mass composition in the trunk of the subjects. The major muscles tested in the bent-over for are within the trunk of the body. The lean muscle mass composition for the entire right lower extremity was compared to the 1RM of the leg press. The results show a fairly strong relationship between muscle mass and strength, for all comparisons ($R^2 = 0.701-0.885$), although there is still an appreciable amount of variation in muscle mass not explained by 1RM (11 to 30%).
Figure 2(A-D): Comparison of actual one-repetition maximum (kg) to the amount of muscle mass in the corresponding body segment (g) for all muscle groups. 
*Only 4 male subjects due to not being able to obtain a 1RM for the 5th subject with the available equipment.

Strength Comparisons between Women and Men

Figures 3 through 5 represent the results for the primary objective of determining if strength differences between sexes could account for preferred child carrying differences. Figure 3 shows the average 1RM for both men and women. For all of the exercises, the men had at least twice as high of an average as the women. The men had an average 1RM three times as high as the women for the shoulder press. These results show statistically significant differences between the 1RM’s for men and women. There was not a significant difference in the 1RM between the right and left sides for the arm curl or the bent-over row.

Figure 4 shows the average 1RM as compared to the 11-kg toddler model. Carrying the 11-kg toddler model was the task that needed to be completed by the subjects for this study. Their muscles needed to be strong enough to lift and support the model while walking at a variety of speeds and complete the desired task. The toddler model weighed on average 90% of the maximum amount of the weight that the women on average could lift with the arm curl.
compared to 50% for the men. All of the exercises were statistically significantly different between the men and women. The toddler model was about 50% on average of the shoulder press maximum for women versus only about 20% for the men.

Figure 5 compares the 1RM is compared to the body mass of the person. This comparison tests strength relative to their physical size. The differences between men and women are not significant for the arm curl and the bent-over row. This means that both the women and men lifted similar percentages of their body weight when performing the 1RM for these exercises. The women are just as strong as the men in comparison to size. The men were only able to lift more weight in those exercises because they are bigger in physical size. The difference between men and women is statistically significant for the leg press and shoulder press. In these exercises the men were able to lift a greater percentage of their body weight than the women.

![Figure 3: Average 1RM for all of the muscle groups and the difference between men and women. Error bars represent ±1 SE. *Represents statistically significant (p<0.05)](image-url)
Figure 4: Comparison of the 11-kg toddler model to the absolute strength of the average actual 1RM in both men and women. Error bars represent ±1 SE. *Represents statistically significant (p<0.05)

Figure 5: The comparison of the average actual 1RM to body mass in both men and women. Error bars represent ±1 SE. *Represents statistically significant (p<0.05)

Poll on Sex Carrying Differences

Other subjective data were collected to help understand the observed differences in carrying positions between men and women. During an oral presentation participants were
asked a quick survey at the beginning. There were about 48 participants 22% men and 78% women. All of the participants believed that women were more likely to carry children on their hip. A total of 91% of the participants believed that men were more likely than women to carry children on their shoulders. Also, 38% of the participants believed that carrying a child on the shoulders is dangerous.

**Postural Comparisons**

The videos of the treadmill trials were reviewed to look for hip adjustments and a trunk tilt while walking and carrying the toddler model in different positions. Every subject stood straight up while carrying the toddler model on their shoulders. Almost all of the subjects hunched their backs forward when wearing the weight belt and carrying the toddler model on the hip (n=8). The lateral adjustment of the hips was looked at from behind the subject treadmill footage. There was no difference between men and women and the occurrence of sticking their hip out to make a “shelf” for the toddler model to sit on. There was a slightly significant difference between the slow speed and the fast speed (p= 0.08). All of the female subjects carried the toddler model at the iliac crest and two of the males carried the model below the iliac crest and one of the male subjects carried the model above the iliac crest.

**Discussion**

**Comparison of Actual and Predicted 1RM**

The methodological results compared the different ways of determining strength. The gold standard is currently the 1RM. Figure 1 shows that the Bryzki’s prediction equation (equation 1) accurately predicts the 1RM for both men and women and all muscle groups. Mayhew et al. (2004) also found that the Brzycki’s equation was not statistically different than
the actual 1RM. This study tested 10 prediction equations and only two of the equations were found to not be statistically different from the actual 1RM. Only high school aged male athletes were used in their study and the participants only completed the bench press for their strength measures. Most of the publicized submaximal prediction equations have a large range of variation. The Brzycki’s equation was shown to accurately predict a 1RM for adults, both sexes, and a variety of muscle groups. The equation estimates slightly lower than the 1RM, but it would still be an accurate measurement for the determination of strength. If one were concerned about muscle damage then using the submaximal repetitions as input to equation 1 would be an adequate replacement for the 1RM testing. Testing to a sub-maximal level could also decrease the time needed to collect the data.

**Comparison of Actual 1RM and Muscle Mass**

The second methodological result was the comparison of the amount of lean muscle mass and the weight lifted during the 1RM. Figure 2 shows that while there is a relationship between the amount of muscle mass and the 1RM, but there is an appreciable amount of variation in muscle mass that is not accounted for by the 1RM (11 to 30%). The DEXA measured the amount of muscle in a given segment and not the absolute strength. For instance, someone with a short arm that lifted many weights would have a similar amount of lean muscle tissue as a person with a really long non-bulky arm. The first person may be able to lift much more weight than the second due to training and the density of the muscle tissue in a small area and many other physiological factors. If one wants to test for strength either a 1RM or equation 1 should be used for a measure and if composition is desired then a DEXA scan should be performed keeping in mind that the two should not be used interchangeably.
**Strength Comparisons between Women and Men**

As was previously discussed, it is commonly observed that men and women often carry children differently. Many generally believed that men are more likely to carry children on their shoulders and women are more likely to carry them on their hip.\(^8\)\(^9\) No studies have been done to quantify this observation. There have also been no studies to explain the reasons for choosing one position over the other.

Men are often able to lift more weight than women (Figure 3). The men are also often larger than most women. There are some people within each sex that are different from the norm. When accounting for relative strength of the person, the average strength of men and women was comparable for both the arm curl and bent-over row. The absolute amount that the men could lift was statistically higher than the women. Task of carrying a toddler requires an absolute strength. The toddler weighed an absolute amount of 11 kg. The more weight the subject was able to lift the less of a strain it would be to lift an 11 kg toddler model. The men may be more able to carry the toddler model on their shoulders, because of the fact that the model weighed about 55% of the maximum amount of the average weight that the women on average could lift onto their shoulders and only about 18% of the average maximum for the men (Figure 4). Therefore it would take less effort for the men to lift the toddler on to their shoulders. Lifting over half the maximum amount of weight that one could lift is a more difficult task than lifting 18% which is a relatively easy amount of weight to lift.

The toddler model was also about 90% of the maximum amount of weight that the women could arm curl where as it was about 50% for the men (Figure 4). This could explain my observation that many female subjects lifted the child to their hip with two arms. The weight
of a child is too much to lift with one arm. Since the weight of a child is a larger burden for the bicep arm muscles, the women may tend to carry with two arms and place the child on the iliac crest. The observational results showed that both men and women often used two arms when carrying the child on the hip.

These child carrying observations are not true for all cultures. There are some cultures that have the women carrying children on their shoulders the majority of the time. The women of Alyawara tribe of central Australia, generally carry their children on their shoulders. They often have to travel in the water and carrying children on their shoulders ensures that the child’s head is above water. The In the western culture many women also believe that carrying a child on the shoulders is dangerous. Additional weight above the head does raise the center of mass and therefore makes a person more unstable. Additional weight to one side of the body also changes the center of mass. The additional weight on one side of the body causes the center of mass to move to that side of the body and therefore causes gait changes. The body mechanics change in both of the carrying positions.

There are still more possible explanations for the suspected child carrying differences. Data for comparing the metabolic differences between the carrying positions have been collected, but have yet to be analyzed. One of the positions may be more economical than the other. It is hypothesized that the shoulder will be more cost effective. Raising the center of mass up should not affect the gait as much as shifting the center of mass to the side. When the center of mass is shifted to the side more abdominal muscles and leg muscles are used in walking then with a normal center of mass. If this is true the strength required to get a child on to the shoulders may be the reason that women do not put a child on to their shoulders as
often in western culture. Another explanation for the observed child carrying differences may be the idea of gender roles. Many more women than men are concerned with the safety of carrying a child on their shoulders. Also often when women are picking up children they are in a hurry and have a task that needs to be completed. The strength required to lift a child on to their shoulders may be too difficult a task when in a hurry. The energy that may be saved with the carrying a child on their shoulders position may not be enough to save from the exertion of lifting the child up initially.

The next part of this research would be to examine the use of modern tools. There are many carrying devices that are available to parents. These devices allow the parents to keep both of their hands free and know that their child is close. The sling was proven to save energy when it was used for infants (Wall-Scheffler et al 2007). The modern toddler carrying devices may also save energy or they may just be beneficial for the convenience that they give to parents.


