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RESEARCH

# Optimizing resistance training intensity in supportive care for survivors of breast cancer: velocity-based approach in the row exercise

David M. Díez-Fernández[1,2] · Alba Esteban-Simón[1,2] · Andrés Baena-Raya[1,2] · Alejandro Pérez-Castilla[1,2] · Manuel A. Rodríguez-Pérez[1,2] · Alberto Soriano-Maldonado[1,2]

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## Abstract

**Purpose** Resistance training mitigates side effects during and after cancer treatment. To provide a new approach for precisely and safely assessing and prescribing the intensity of resistance training in supportive cancer care, the purpose of this study was to evaluate the load-velocity relationship during the row exercise in women survivors of breast cancer.

**Methods** Twenty women survivors of breast cancer who had undergone surgery and had completed core breast cancer treatment within the previous 10 years completed an incremental loading test until the one repetition maximum (1RM) in the row exercise. The velocity was measured during the concentric phase of each repetition with a linear velocity transducer, and their relationship with the relative load was analyzed by linear and polynomial regression models.

**Results** A strong relationship was observed between movement velocity and relative load for all measured velocity variables using linear and polynomial regression models ($R^2 > 0.90$; SEE < 6.00%1RM). The mean velocity and mean propulsive velocity of 1RM was $0.40 \pm 0.03$ m·s$^{-1}$, whereas the peak velocity at 1RM was $0.64 \pm 0.07$ m·s$^{1}$.

**Conclusion** In women survivors of breast cancer, monitoring movement velocity during the row exercise can facilitate precise assessment and prescription of resistance training intensity in supportive cancer care.

**Keywords** Supportive care in cancer · Exercise cancer rehabilitation · Resistance training · Velocity-based training · Load-velocity profile · Upper-limb strength

✉ David M. Díez-Fernández
daviddiez@ual.es

Alba Esteban-Simón
aes167@ual.es

Andrés Baena-Raya
abr589@ual.es

Alejandro Pérez-Castilla
alexperez@ual.es

Manuel A. Rodríguez-Pérez
manolo.rodriguez@ual.es

Alberto Soriano-Maldonado
asoriano@ual.es

[1] Department of Education, Faculty of Education Sciences, University of Almería, Carr. Sacramento, S/N, 04120 La Cañada, Almería, Spain

[2] SPORT Research Group (CTS-1024), CIBIS (Centro de Investigación para el Bienestar y la Inclusión Social) Research Center, University of Almería, Carr. Sacramento, S/N, 04120 La Cañada, Almería, Spain

## Introduction

Breast cancer incidence rates in women have increased by approximately 0.6% annually since the mid-2000s, while mortality rates have decreased by 1% annually from 2013 to 2021 [1]. Such reduced mortality rates led to an increased number of survivors of breast cancer that may face various medical, physical, and psychosocial consequences affecting their overall health and well-being [2]. Compelling evidence supports the efficacy of resistance training for ameliorating breast cancer-related side effects [3–5]. The American College of Sports Medicine (ACSM) guidelines for cancer survivors recommend resistance training with an intensity of 60–80% of the one-repetition maximum (1RM) to significantly improve physical fitness, restore physical functioning, enhance quality of life, and mitigate fatigue during and after cancer treatment [6]. Thus, developing accurate methods to measure relative load (%1RM) without excessive effort are crucial for enhancing resistance training prescription in supportive cancer care for women survivors of breast cancer.

The use of movement velocity allows accurate quantification, monitoring, and prescription of %1RM during resistance training, eliminating the requirement for maximal lifts (1RM) and reducing the potential impact on blood pressure, and muscle and bone stress [7]. This method also avoids the necessity of performing repetitions to failure (XRM), which may induce significant fatigue due to excessive mechanical and metabolic strain [8]. Recent studies have already used the load-velocity relationship to estimate the %1RM among clinical populations, including multiple sclerosis [9], older adults [10–12], and breast cancer survivors [13, 14]. This is especially relevant in survivors of breast cancer as fatigue has been suggested as a major limiting factor to exercise [15].

The row exercise is a key multi-joint exercise commonly implemented within training programs in cancer survivors [16–19]. It comprises pulling the bar toward the chest, involving both shoulder extension and elbow flexion [20]. Specifically, in survivors of breast cancer, this movement involves structures primarily affected by local treatments for this disease. The most common breast reconstructions after breast cancer involve the use of autologous tissue, traditionally utilizing the latissimus dorsi muscle [21], although current methods in breast reconstruction using dorsal flaps are designed to spare the latissimus dorsi muscle [22]. Acute complications for breast reconstruction include skin necrosis, seroma, donor site morbidly, and total or partial flap loss [23]. Therefore, the row exercise might help patients to improve strength during the follow-up of adjuvant breast cancer therapy and address functional after-effects following breast reconstruction. However, the load-velocity relationship obtained during the main variants of the rowing exercise has not been investigated in cancer patients or in individuals with clinical conditions. In contrast, in healthy young participants, recent studies found favorable results supporting the implementation of the load-velocity relationship as an evaluation and programming approach for the bent over row exercise performed on a Smith machine [24, 25]. However, given that the velocity associated with submaximal loads in survivors of breast cancer has been demonstrated to be different to other populations [13], further research is needed to individualize training prescription for this clinical population. In addition, several methodological aspects such as the velocity variable [26] or the regression model [27] used in establishing the load-velocity relationships remain unresolved.

Considering the above gaps, the aims of this study were the following: (i) to evaluate the load-velocity relationship during the bent over row exercise in women survivors of breast cancer, (ii) to assess which velocity variable (mean velocity [MV], mean propulsive velocity [MPV], or peak velocity [PV]) shows a stronger relationship with relative loads (%1RM), and (iii) to examine whether regression models (linear or polynomial) differ in predicting the velocities associated with each %1RM.

## Methods

### Participants

A total of 20 women volunteered to participate in this study. All participants had undergone breast surgery and had completed breast cancer core treatment (chemotherapy or radiotherapy) within the previous 10 years. The participants' characteristics are presented in Table 1. The exclusion criteria were as follows: (1) metastatic breast cancer; (2) breast reconstruction performed less than 3 months before; and (3) having any comorbidity that might contraindicate the performance of a maximum test. The present research was conducted in accordance with the Helsinki Declaration and was approved by the Local Ethics Committee. After being informed of the purpose of the study and the experimental procedures, the participants signed a written informed consent form prior to participation.

### Study design

A descriptive cross-sectional study was conducted to assess the load-velocity relationship obtained during the bent over row exercise in women survivors of breast cancer. An incremental loading test was used to determine the full load-velocity relationship. The participants underwent a

**Table 1** Descriptive characteristics of the study participants

| Physical characteristics | Mean ± SD |
|---|---|
| Age (years) | 56.45 ± 8.34 |
| Body mass (kg) | 72.84 ± 13.05 |
| Body height (cm) | 161.95 ± 6.14 |
| BMI (kg·m$^{-2}$) | 27.87 ± 5.39 |
| 1RM row (kg) | 47.35 ± 7.90 |
| 1RM row (normalized per kg of body mass) | 0.66 ± 0.09 |
| Medical information | *n* (%) |
| Time since diagnosis (years, mean ± SD) | 5.95 ± 4.29 |
| Treatment | |
| Chemotherapy | 13 (65) |
| Radiotherapy | 17 (85) |
| Hormone therapy | 15 (75) |
| Surgical procedure | |
| Tumerectomy | 12 (60) |
| Mastectomy | 8 (40) |

*SD*, standard deviation; *BMI*, body mass index (kg·m-2); *1RM*, one-repetition maximum preliminary 10-week supervised resistance exercise program with 2 group-based (4–6 participants) training sessions per week (a total of 20 sessions of 60 min). During these sessions, the participants got familiarized with the bent over row exercise while the exercise professional emphasized the technique and the intention to move the loads at maximum velocity of the concentric phase. The individualized load-velocity relationships were modulated using thee different velocity variables: (1) MV: the average velocity from the start of the upward movement (i.e., the first positive velocity value) until the barbell reaches the maximum height (i.e., the velocity is 0 $m \cdot s^{-1}$); (2) MPV: the average velocity during the impulsive phase, defined as the part of the concentric phase during which the measured acceleration is greater than the acceleration due to gravity (i.e., $a \geq -9.81\ m \cdot s^{-2}$) [28]; and (3) PV: the highest velocity value recorded at a particular instant ($m \cdot s^{-1}$) during the concentric phase. The individualized load-velocity relationships were modulated by two different regression models: linear and polynomial.

## Testing procedures

Participants attended a previous medical check-up to assess whether they had any contraindications for performing a maximum physical effort (i.e., a direct 1RM test). Additionally, body height and body mass were measured using a wall-mounted stadiometer (Seca 202, Seca Ltd., Hamburg, Germany) and a digital scale (Seca 899, Seca Ltd., Hamburg, Germany), respectively. All testing sessions were conducted under similar environmental conditions (~ 21 °C and ~ 60% humidity) and in the same place (sport research laboratory). Strong verbal stimulation was provided during testing to motivate the participants to exert at maximum effort.

Bent over row exercise was performed using a Smith machine (Multipower Fitness Line, Peroga, Murcia, Spain) (Fig. 1). Participants stood with both feet flat on the floor, flexed knees, inclined trunk, and fully extended arms. Form that position, they were instructed to pull the barbell as fast as possible until it contacted the telescopic holders (mechanical brake) of the Smith machine. The height of the telescopic holders was individually set to ensure safe and comfortable lifting at the maximum intended velocity. A momentary pause (~ 1 s) was imposed between the downward and upward movements to avoid the rebound of the barbell with the telescopic. Repetitions that did not contact with the telescopic holders of the Smith machine or that significantly modified the position of the knees and/or the trunk during execution were excluded and a new set was performed with the same absolute load after the corresponding resting period. Similarly, when the proposed load was not displaced, after the relevant rest (~ 4 min), a new attempt was made with the same absolute load to verify that the

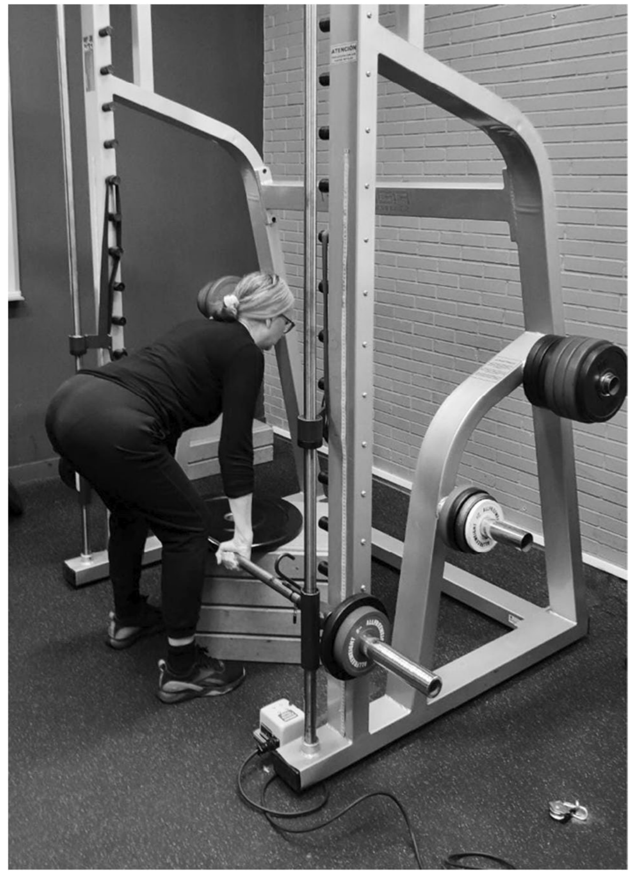

**Fig. 1** Row exercise, Smith machine, and linear velocity transducer during test

participants were not actually able to displace that load. The barbell velocity of all repetitions was recorded with a linear velocity transducer (T-Force System, Ergo-Tech, Murcia, Spain). The validity and reliability of this system have been studied previously [29].

The warm-up protocol consisted of 5 min walking at a self-selected intensity, 2 min of upper-body dynamic joint mobility, a set of 10 repetitions performing bent over row exercise without additional weight, and a set of 6 repetitions with 14 kg (mass of unloaded Smith machine barbell) gradually increasing movement velocity. Based on a previous study conducted in the bent over Smith machine row exercise [25], the initial external load of the incremental loading test was set at 14 kg and was progressively increased in 10–5 kg and 5–2.5 kg increments until the attained MPV was ~ 1.00 $m \cdot s^{-1}$ (~ 50% 1RM) and ~ 0.65 $m \cdot s^{-1}$ (~ 85% 1RM), respectively. From that movement, the load was progressively increased in steps of 2 to 1 kg, until the 1RM strength was determined. The last load that was correctly displaced completing the appropriate range of motion was determined as the 1RM strength. During the incremental loading test, the participants performed 3 repetitions at low loads (> 1.00 m·s$^{-1}$), 2 at medium loads (1.00–0.65 m·s$^{-1}$) and only 1 at high loads (< 0.65 m·s$^{-1}$). The recovery time between sets ranged from 3 min (low and medium loads) to 4 min (high loads). Only the best repetition (i.e., that with the highest value of each velocity variable) of each set was considered for further analyses.

### Statistical analysis

The descriptive data are presented as the mean and standard deviation, calculated using standardized statistical methods. The normal distribution of the data was confirmed by the Shapiro–Wilk test ($p > 0.05$). To assess the association between the relative load (%1RM) and velocity variables (MV, MPV, and PV), the linear and quadratic regression (second-degree polynomial) models were used. The goodness of fit was assessed by the Pearson's multivariate coefficient of determination ($R^2$) and the standard error of the estimate (SEE). The differences between linear and polynomial fits were compared using a paired samples *t*-test and using *Hedge's g* effect sizes (ES) [30]. The following scale was used for ES interpretation: trivial (< 0.20), small (0.20 to < 0.60), moderate (0.60 to < 1.20), large (1.20 to < 2.00), and extremely large (> 2.00) [31]. The between-subject coefficient of variation (CV) was calculated to determine the variability of the velocity values associated with each %1RM. A CV < 10% was determined as an acceptable level of variability. The significance level was set at 5% ($p < 0.05$). The SPSS version 29 statistical software package (SPSS, Chicago, IL) was used for the analysis.

## Results

The 1RM mean value for the bent over row exercise was 47.35 ± 7.90 kg (0.66 ± 0.09 normalized per kg of body weight). The number of loads used for the 1RM measurement was 6.75 ± 1.02. The MV and MPV of 1RM was 0.40 ± 0.03 m·s$^{-1}$ (range: 0.35–0.48 m·s$^{-1}$), whereas the PV at 1RM was 0.64 ± 0.07 m·s$^{-1}$ (range: 0.51–0.79 m·s$^{-1}$).

### Relationship between relative load and movement velocity

The linear and quadratic fits individually analyzed for the MV resulted in $R^2$ values of 0.982 ± 0.012 (range: 0.958–0.997; CV = 1.2%) and 0.986 ± 0.010 (range: 0.959–0.998; CV = 1.1%), respectively. For the MPV variable, the individually analyzed linear and quadratic fits showed average $R^2$ values of 0.982 ± 0.011 (range: 0.962–0.995; CV = 1.1%) and 0.986 ± 0.009 (range: 0.969–0.997; CV = 0.9%), respectively. For the PV variable, the individually analyzed linear and quadratic fits showed average values of $R^2$ = 0.969 ± 0.025 (range: 0.911–0.994; CV = 2.6%) and 0.981 ± 0.017 (range: 0.926–0.998; CV = 1.7%), respectively.

Taking all the data as a whole, a strong relationship ($R^2 > 0.90$) was observed between the three velocity variables and the %1RM using linear and polynomial fits:

- Relationship of MV with the %1RM using a linear fit $R^2$ = 0.944; SEE = 0.06 m·s$^{-1}$ (Fig. 2A) and a polynomial fit $R^2$ = 0.945; SEE = 0.06 m·s$^{-1}$ (Fig. 2B).
- Relationship of MPV with the %1RM using a linear fit $R^2$ = 0.939; SEE = 0.07 m·s$^{-1}$ (Fig. 2C) and a polynomial fit $R^2$ = 0.939; SEE = 0.07 m·s$^{-1}$ (Fig. 2D).
- Relationship of PV with the %1RM using a linear fit $R^2$ = 0.936; SEE = 0.12 m·s$^{-1}$ (Fig. 2E) and a polynomial fit $R^2$ = 0.942; SEE = 0.11 m·s$^{-1}$; (Fig. 2F).

### Differences between regression models and velocity variables

Tables 2, 3, and 4 present the MV, MPV, and PV data analyzed using linear and polynomial fits in the individualized load-velocity relationship, starting from 20% 1RM and progressing in 5% increments. For mean velocity variables (MV and MPV), we found that no significant differences were observed between regression models and the maximum difference was only 0.01 m·s$^{-1}$. However, significant differences and a moderate effect size between linear and polynomial fits were detected in the PV (Table 4) particularly at medium loads (65–75% 1RM: $p < 0.001$; ES ≥ 0.60).

The three velocity variables showed a similar level of consistency for both fits, although the linear fit demonstrated slightly lower subject's variability for all velocity variables. In average, the MV, MPV, and PV variable using both fit showed an acceptable variability (CV < 10%). The between-subject variability in the incremental test was slightly lower for MV and PV compared to MPV.

### Prediction of the relative load (%1RM) using the movement velocity

The prediction equations for estimating the relative load (%1RM) from the MV data (in m·s$^{-1}$) were:

- Load (%1RM) = − 89.98 MV + 135.31 [$R^2$ = 0.944; SEE = 5.68%1RM] using the linear fit.
- Load (%1RM) = 23.17·MV$^2$ − 126.73 MV + 148.21 [$R^2$ = 0.949; SEE = 5.43%1RM] using the polynomial fit.

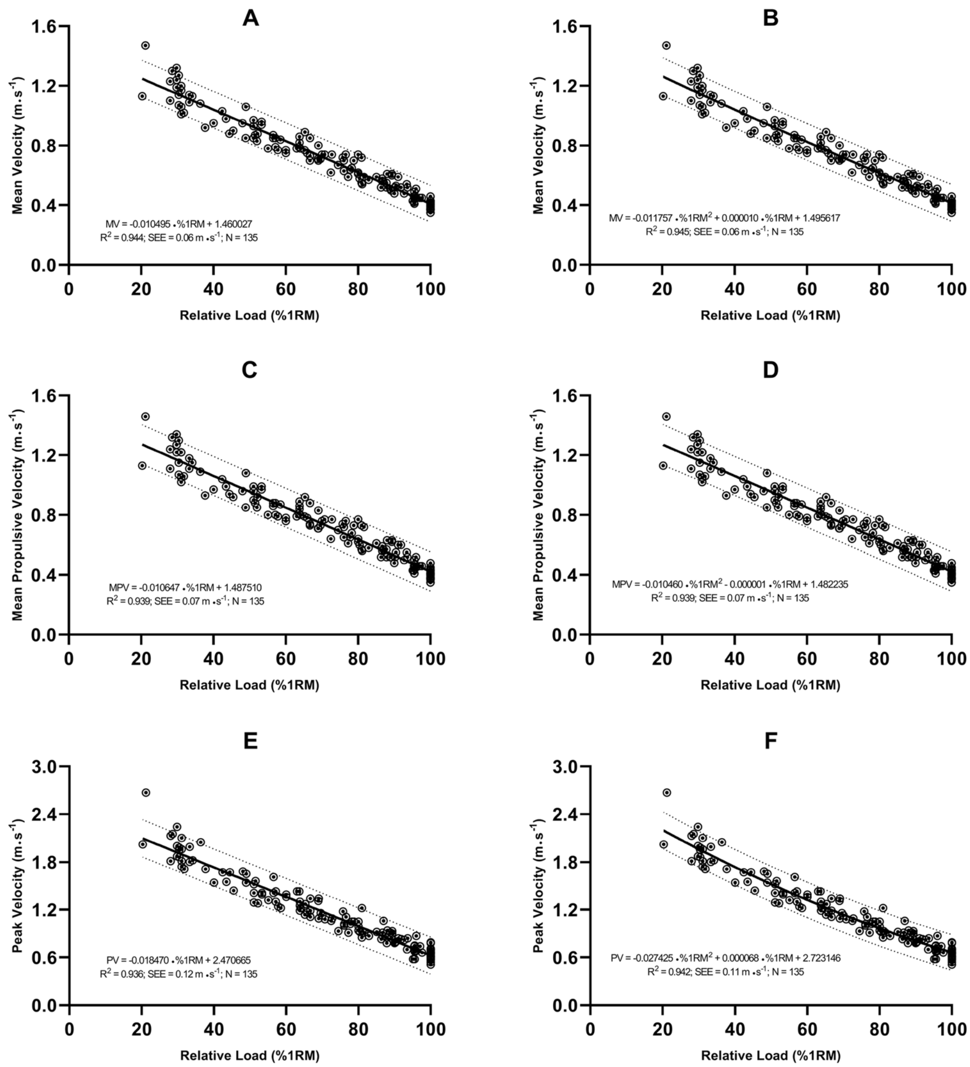


**Fig. 2** Relationship between the relative load (% 1RM) and **A** and **B** the MV, **C** and **D** the MPV, and the PV (**E** and **F**) using a linear and polynomial fit. $R^2$, coefficient of determination; SEE, standard error of the estimate; N, number of observations; Dotted lines indicate the 95% prediction bands

In cases where MPV data (in m·s$^{-1}$) were used, the resulting equations were:

- Load (%1RM) = − 88.22 MPV + 135.52 [$R^2$ = 0.939; SEE = 5.94%1RM] using the linear fit.
- Load (%1RM) = 15.42 MPV$^2$ − 112.96 MPV + 144.31 [$R^2$ = 0.942; SEE = 5.84%1RM] using the polynomial fit.

In cases where PV data (in m·s$^{-1}$) were used, the resulting equations were:

- Load (%1RM) = − 50.69 PV + 129.73 [$R^2$ = 0.936; SEE = 6.08%1RM] using the linear fit.
- Load (%1RM) = 11.78 PV$^2$ − 82.12 PV + 147.93 [$R^2$ = 0.950; SEE = 5.40%1RM] using the polynomial fit.

## Discussion

This study was designed to evaluate the load-velocity relationship during the bent over row exercise in women survivors of breast cancer. The main findings revealed (i) a strong relationship between the movement velocity and the relative load (%1RM) during the bent over row exercise, (ii) all velocity variables demonstrated comparable associations with %1RM and a similar level of consistency, and (iii) both regression models predicted the velocities associated with each %1RM with comparable precision. Hence, assessing movement velocity is an accurate method for monitoring and adjusting resistance training intensity during the bent over row exercise in women survivors of breast cancer. In addition, the velocity variable and regression model do not seem to be important methodological factors in this exercise, as they do not affect the accuracy of the load-velocity relationship.

**Table 2** Mean velocity ($m \cdot s^{-1}$) associated with each relative load obtained from the individualized load-velocity relationship with a linear and polynomial fit

| Relative load (%1RM) | Linear fit | | Polynomial fit | | Differences between fits | | |
|---|---|---|---|---|---|---|---|
| | Mean ± SD ($m \cdot s^{-1}$) | CV (%) | Mean ± SD ($m \cdot s^{-1}$) | CV (%) | Mean ± SD ($m \cdot s^{-1}$) | *p* | ES |
| 20% | 1.25 ± 0.09 | 7.4 | 1.26 ± 0.12 | 9.3 | −0.01 ± 0.05 | 0.563 | −0.06 |
| 25% | 1.20 ± 0.09 | 7.2 | 1.21 ± 0.10 | 8.5 | −0.00 ± 0.04 | 0.638 | −0.04 |
| 30% | 1.15 ± 0.08 | 7.1 | 1.15 ± 0.09 | 7.8 | −0.00 ± 0.02 | 0.742 | −0.02 |
| 35% | 1.10 ± 0.08 | 6.9 | 1.10 ± 0.08 | 7.2 | 0.00 ± 0.01 | 0.949 | 0.00 |
| 40% | 1.04 ± 0.07 | 6.7 | 1.04 ± 0.07 | 6.8 | 0.00 ± 0.01 | 0.259 | 0.02 |
| 45% | 0.99 ± 0.06 | 6.5 | 0.99 ± 0.06 | 6.4 | 0.00 ± 0.01 | 0.093 | 0.05 |
| 50% | 0.94 ± 0.06 | 6.3 | 0.94 ± 0.06 | 6.2 | 0.00 ± 0.01 | 0.149 | 0.07 |
| 55% | 0.89 ± 0.05 | 6.1 | 0.88 ± 0.05 | 6.1 | 0.00 ± 0.02 | 0.220 | 0.09 |
| 60% | 0.83 ± 0.05 | 5.9 | 0.83 ± 0.05 | 6.0 | 0.01 ± 0.02 | 0.249 | 0.10 |
| 65% | 0.78 ± 0.04 | 5.7 | 0.78 ± 0.05 | 6.0 | 0.00 ± 0.02 | 0.276 | 0.11 |
| 70% | 0.73 ± 0.04 | 5.6 | 0.72 ± 0.04 | 6.0 | 0.00 ± 0.02 | 0.296 | 0.11 |
| 75% | 0.68 ± 0.04 | 5.4 | 0.67 ± 0.04 | 6.0 | 0.00 ± 0.02 | 0.299 | 0.10 |
| 80% | 0.62 ± 0.03 | 5.4 | 0.62 ± 0.04 | 6.0 | 0.00 ± 0.01 | 0.284 | 0.09 |
| 85% | 0.57 ± 0.03 | 5.6 | 0.57 ± 0.03 | 5.9 | 0.00 ± 0.01 | 0.287 | 0.05 |
| 90% | 0.52 ± 0.03 | 6.0 | 0.52 ± 0.03 | 6.0 | 0.00 ± 0.00 | 0.460 | 0.01 |
| 95% | 0.47 ± 0.03 | 6.7 | 0.47 ± 0.03 | 6.4 | −0.00 ± 0.01 | 0.390 | −0.06 |
| 100% | 0.41 ± 0.03 | 7.9 | 0.42 ± 0.03 | 7.5 | −0.00 ± 0.02 | 0.362 | −0.13 |
| Average | 0.83 ± 0.05 | 6.4 | 0.83 ± 0.06 | 6.7 | 0.00 ± 0.02 | 0.383 | 0.03 |

*1RM*, one-repetition maximum; *SD*, standard deviation; *CV*, coefficient of variation; *p*, *p*-value between linear and polynomial fits; *ES*, effect size between linear and polynomial fits

**Table 3** Mean propulsive velocity ($m \cdot s^{-1}$) associated with each relative load obtained from the individualized load-velocity relationship with a linear and polynomial fit

| Relative load (%1RM) | Linear fit | | Polynomial fit | | Differences between fits | | |
|---|---|---|---|---|---|---|---|
| | Mean ± SD ($m \cdot s^{-1}$) | CV (%) | Mean ± SD ($m \cdot s^{-1}$) | CV (%) | Mean ± SD ($m \cdot s^{-1}$) | *p* | ES |
| 20% | 1.28 ± 0.10 | 7.6 | 1.27 ± 0.12 | 9.3 | 0.01 ± 0.06 | 0.449 | 0.09 |
| 25% | 1.23 ± 0.09 | 7.5 | 1.22 ± 0.11 | 8.6 | 0.01 ± 0.04 | 0.416 | 0.08 |
| 30% | 1.17 ± 0.09 | 7.4 | 1.17 ± 0.09 | 8.0 | 0.01 ± 0.03 | 0.362 | 0.06 |
| 35% | 1.12 ± 0.08 | 7.2 | 1.12 ± 0.08 | 7.5 | 0.00 ± 0.02 | 0.260 | 0.05 |
| 40% | 1.07 ± 0.08 | 7.1 | 1.06 ± 0.08 | 7.2 | 0.00 ± 0.01 | 0.135 | 0.04 |
| 45% | 1.01 ± 0.07 | 7.0 | 1.01 ± 0.07 | 6.9 | 0.00 ± 0.01 | 0.297 | 0.02 |
| 50% | 0.96 ± 0.07 | 6.8 | 0.96 ± 0.07 | 6.8 | 0.00 ± 0.01 | 0.842 | 0.01 |
| 55% | 0.91 ± 0.06 | 6.7 | 0.91 ± 0.06 | 6.8 | −0.00 ± 0.02 | 0.954 | 0.00 |
| 60% | 0.85 ± 0.06 | 6.5 | 0.85 ± 0.06 | 6.8 | −0.00 ± 0.02 | 0.854 | −0.01 |
| 65% | 0.80 ± 0.05 | 6.4 | 0.80 ± 0.06 | 6.9 | −0.00 ± 0.02 | 0.747 | −0.03 |
| 70% | 0.75 ± 0.05 | 6.3 | 0.75 ± 0.05 | 7.0 | −0.00 ± 0.02 | 0.787 | −0.02 |
| 75% | 0.69 ± 0.04 | 6.3 | 0.69 ± 0.05 | 7.0 | −0.00 ± 0.02 | 0.738 | −0.03 |
| 80% | 0.64 ± 0.04 | 6.4 | 0.64 ± 0.04 | 7.0 | −0.00 ± 0.01 | 0.714 | −0.02 |
| 85% | 0.59 ± 0.04 | 6.5 | 0.59 ± 0.04 | 6.9 | −0.00 ± 0.01 | 0.674 | −0.02 |
| 90% | 0.53 ± 0.04 | 6.9 | 0.53 ± 0.04 | 7.0 | 0.00 ± 0.00 | 0.761 | 0.00 |
| 95% | 0.48 ± 0.04 | 7.6 | 0.48 ± 0.03 | 7.2 | 0.00 ± 0.01 | 0.647 | 0.03 |
| 100% | 0.43 ± 0.04 | 8.7 | 0.42 ± 0.03 | 8.2 | 0.00 ± 0.02 | 0.654 | 0.06 |
| Average | 0.85 ± 0.06 | 7.0 | 0.85 ± 0.06 | 7.4 | 0.00 ± 0.02 | 0.605 | 0.02 |

*1RM*, one-repetition maximum; *SD*, standard deviation; *CV*, coefficient of variation; *p*, *p*-value between linear and polynomial fits; *ES*, effect size between linear and polynomial fits

**Table 4** Peak velocity (m·s$^{-1}$) associated with each relative load obtained from the individualized load-velocity relationship with a linear and polynomial fit

| Relative load (%1RM) | Linear fit | | Polynomial fit | | Differences between fits | | |
|---|---|---|---|---|---|---|---|
| | Mean ± SD (m·s$^{-1}$) | CV (%) | Mean ± SD (m·s$^{-1}$) | CV (%) | Mean ± SD (m·s$^{-1}$) | $p$ | ES |
| 20% | 2.09 ± 0.17 | 8.2 | 2.18 ± 0.23 | 10.4 | − 0.09 ± 0.12 | 0.003* | − 0.45 |
| 25% | 2.00 ± 0.16 | 7.9 | 2.06 ± 0.19 | 9.3 | − 0.06 ± 0.09 | 0.003* | − 0.36 |
| 30% | 1.91 ± 0.14 | 7.6 | 1.95 ± 0.16 | 8.3 | − 0.04 ± 0.06 | 0.004* | − 0.26 |
| 35% | 1.82 ± 0.13 | 7.2 | 1.84 ± 0.14 | 7.5 | − 0.02 ± 0.03 | 0.010* | − 0.15 |
| 40% | 1.73 ± 0.12 | 6.9 | 1.73 ± 0.12 | 6.8 | − 0.00 ± 0.01 | 0.444 | − 0.02 |
| 45% | 1.63 ± 0.11 | 6.5 | 1.62 ± 0.10 | 6.2 | 0.01 ± 0.02 | 0.002* | 0.11 |
| 50% | 1.54 ± 0.09 | 6.1 | 1.52 ± 0.09 | 5.8 | 0.02 ± 0.03 | 0.001** | 0.25 |
| 55% | 1.45 ± 0.08 | 5.6 | 1.42 ± 0.08 | 5.6 | 0.03 ± 0.04 | 0.001** | 0.39 |
| 60% | 1.36 ± 0.07 | 5.1 | 1.32 ± 0.07 | 5.5 | 0.04 ± 0.04 | 0.001** | 0.51 |
| 65% | 1.27 ± 0.06 | 4.7 | 1.23 ± 0.07 | 5.4 | 0.04 ± 0.04 | 0.001** | 0.60 |
| 70% | 1.18 ± 0.05 | 4.3 | 1.14 ± 0.06 | 5.4 | 0.04 ± 0.04 | 0.001** | 0.65 |
| 75% | 1.09 ± 0.04 | 4.1 | 1.05 ± 0.06 | 5.3 | 0.03 ± 0.04 | 0.001** | 0.65 |
| 80% | 0.99 ± 0.04 | 4.1 | 0.97 ± 0.05 | 5.2 | 0.03 ± 0.03 | 0.001** | 0.54 |
| 85% | 0.90 ± 0.04 | 4.7 | 0.89 ± 0.05 | 5.4 | 0.01 ± 0.02 | 0.001** | 0.32 |
| 90% | 0.81 ± 0.05 | 5.9 | 0.81 ± 0.05 | 6.1 | 0.00 ± 0.01 | 0.625 | 0.01 |
| 95% | 0.72 ± 0.06 | 7.8 | 0.74 ± 0.06 | 8.0 | − 0.02 ± 0.02 | 0.005* | − 0.28 |
| 100% | 0.63 ± 0.07 | 10.6 | 0.67 ± 0.07 | 11.2 | − 0.04 ± 0.05 | 0.003* | − 0.51 |
| Average | 1.36 ± 0.09 | 6.3 | 1.36 ± 0.10 | 6.9 | − 0.00 ± 0.04 | 0.065 | 0.12 |

*1RM*, one-repetition maximum; *SD*, standard deviation; *CV*, coefficient of variation; *p*, *p*-value between linear and polynomial fits. Statistically significant differences $*p < 0.01$; $**p < 0.001$; *ES*, effect size between linear and polynomial fits

Patients during cancer treatment exhibit reduced muscle strength in upper limbs, with an average decrease of 12–16% compared to healthy women. These patients also experience consistently higher muscular fatigue and reduced shoulder flexibility. Overall, cancer patients show notable reductions in muscle strength and joint function, both during and following cancer treatment [32]. The notable differences between cancer patients and healthy individuals highlight the urgent need for early exercise to prevent or mitigate muscle function loss and the adverse effects of chemotherapy. Thus, the relevance of this contribution lies in the critical importance of optimizing resistance training prescriptions for survivors of breast cancer, ensuring the accurate determination of training loads to maximize strength improvements and health-related benefits.

For the first time, we examined the load-velocity relationship during the bent over row exercise in survivors of breast cancer, observing a close relationship between movement velocity and relative load ($R^2 > 0.90$). These results concur with previous evidence indicating that using movement velocity for prescribing and monitoring the relative load in survivors of breast cancer during resistance training are feasible [13, 14, 33]. Although individualized regression equations yields more precise estimations of relative load compared to generalized regresion equations, previous studies have shown that both types of equations accurately predict the relative load in different resistance training exercises [34, 35]. In the present study, the goodness of fit of the generalized regresion equations was very strong for the three velocity variables ($R^2$ ~ 0.94) in the bent over row exercise (Fig. 2). In practical terms, using general equations eliminates the need for direct assessment of the load-velocity relationship, particularly beneficial when working with survivors of cancer. This apporach allows for real-time monitoring of whether participants are training according to the programmed relative load and enables quick and continuos adjustment of the absolute load (kg). This facilitates updating the %RM during the intervention as deemed necessary [36].

Our study suggests that the generalized load-velocity regression equations are specific for survivors of breast cancer, as they seem to be dependent on the sex and on the physical and physiological characteristics of each population. First, our equations presented higher $R^2$ (> 0.90) and lower SEE (< 6.00% 1RM) compared to previous studies that have analyzed the load-velocity relationship during the bent over row exercise in men top-level athletes or in healthy young men and women with at least 2 years of resistance training experience [24, 25]. Similarly, the MPV corresponding to 70% of 1RM in our study was 0.75 m·s$^{-1}$, which differs from those values reported in men top-level athletes (1.03 m·s$^{-1}$) [24], or healthy young men (0.94 $m \cdot s^{-1}$) and women (0.81 $m \cdot s^{-1}$) [25]. This difference remained constant across all submaximal relative loads and at the 1RM load (0.64 ± 0.08 $m \cdot s^{-1}$ in male top-level athletes; 0.49 ± 0.13 $m.s^{-1}$ in health young women; and 0.43 ± 0.04 $m \cdot s^{-1}$ in survivors of breast cancer for the linear fit, to make results comparable), indicating lower velocities associated with each %1RM for women survivors of breast cancer. There are several reasons that may explain these differences: (i) we set up the telescopic holders on the Smith machine to ensure subjects felt secure while performing the concentric phase at the intended maximum velocity and to guarantee completion of the appropriate range of motion; (ii) our participants were familiarized with the intention to move the loads at maximum velocity during the concentric phase; (iii) men are suggested to achieve higher velocities than women in almost all relative loads in different exercises [10, 37]; (iv) the relative bent over row strength value of our participants was lower than that of healthy young women (0.90 ± 0.15 vs. 0.66 ± 0.09 normalized per kg of body weight), and our participants were notably older (56.5 ± 8.3 vs. 24.2 ± 5.2 years) [38]; and (v) there are important physiological and muscular strength differences between survivors of breast cancer and healthy individuals [32, 39]. Collectively, these results highlight the importance of adapting the load-velocity relationship to the characteristics of survivors of breast cancer.

Differences between regression models have not been examined previously in the bent over row exercise. The present findings revealed a similar fit ($R^2$ and SEE) for both models when the data were analyzed in groups, emphasizing that the polynomial fit presents slightly better accuracy for all velocity variables (Fig. 2), as reported by previous literature assessing the load-velocity relationship during the leg press exercise in survivors of breast cancer [13]. However, when analyzing the data individually, the linear fit demonstrated slightly lower subject's variability for all velocity variables (Tables 2, 3, and 4), in line with previous investigations involving different exercises [27, 40]. In addition, no significant differences between both regression models for means velocity variables were observed when the data were analyzed individually (Tables 2, and 3). Nevertheless, significant differences and a moderate effect size between linear and polynomial fits were detected for the PV (Table 4). Although in the present study, when the data were analyzed in groups, the PV showed a good accuracy using polynomial fit ($R^2$, 0.942; SEE, 5.40%), it is important to point out that PV could be more suitable for measuring ballistic movements or weightlifting exercises [41–43].

Limitations of our study need to be considered. We included women who had undergone different breast surgery types (tumerectomy: 60%; mastectomy: 40%) and the time since diagnosis varied across the participants (5.95 ± 4.29 years). Additionally, participants need to be familiarized with the exercise, as the exercise professional emphasizes both the technique and the intention of moving the loads at maximum velocity during the concentric phase. The familiarization phase prior to testing in cancer patients should be sufficiently prolonged (e.g., 2–3 sessions) to ensure that all participants are well-acquainted with the testing approach. These issues could compromise the generalizability of the present results to all women survivors of breast cancer.

In summary, our study establishes the load-velocity relationship in the bent over row exercise for women survivors of breast cancer. Importantly, the velocity variable and the regression model do not appear to be significant methodological factors in this instance. However, the mean velocity using linear fit demonstrated slightly lower subject's variability when the data were analyzed individually. In practice, authors recommend the use of general equations using mean velocity, avoiding the need for a direct assessment of the load-velocity relationship when working with survivors of cancer. In practical terms, the test employed in this study allows for: (a) assessing upper body muscular strength without conducting a traditional test, thus reducing the potential impact on blood pressure, and on muscle and bone stress; (b) determining the level of effort that the patient is exerting, as monitoring is essential to properly control and prescribe resistance training; and (c) controlling the fatigue generated and individualizing the training load, which offers a significant advantage, particularly in cancer patients who experience cancer-related fatigue. Thus, monitoring movement velocity during the row exercise can facilitate precise assessment and prescription of resistance training intensity in supportive cancer care.

**Author contributions** DMD-F participated in the design of the study, contributed to data collection and statistical analysis, wrote original draft; AE-S participated in the design of the study, contributed to data collection; AB-R participated in the design of the study, contributed to data collection; AP-C participated in the design of the study, contributed to data collection, contributed to statistical analysis; MAR-P participated in the design of the study, contributed to data collection, provided resources and carried out project administration.; AS-M participated in the design of the study, obtained funding, provided resources and carried out project administration.

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**Data availability** The datasets are available from the corresponding author upon reasonable request.

## Declarations

**Ethics approval** This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University of Almería, Spain (ref: UALBIO2022/008).

**Consent to participate** Informed consent was obtained from all individual participants included in the study.

**Consent for publication** Owing to the anonymous nature of the data, the requirement for informed consent was waived.

**Competing interests** The authors declare no competing interests.

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