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Reporting of Resistance Training Dose, Adherence, and Tolerance in Exercise Oncology

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ABSTRACT

FAIRMAN, C. M., T. S. NILSEN, R. U. NEWTON, D. R. TAAFFE, N. SPRY, D. JOSEPH, S. K. CHAMBERS, Z. P. ROBINSON, N. H. HART, M. C. ZOURDOS, B. C. FOCHT, C. J. PEDDLE-MCINTYRE, and D. A. GALVÃO. Reporting of Resistance Training Dose, Adherence, and Tolerance in Exercise Oncology. Med. Sci. Sports Exerc., Vol. 52, No. 2, pp. 315–322, 2020. Purpose: While general guidelines (such as CONSORT or Consensus on Exercise Reporting Template) exist to enhance the reporting of exercise interventions in the field of exercise science, there is inadequate detail facilitating the standardized reporting of resistance training adherence in the oncology setting. The purpose of this study was to apply a novel method to report resistance training dose, adherence, and tolerance in patients with cancer. Methods: A total of 47 prostate cancer patients (70.1 ± 8.9 yr, body mass index, 28.6 ± 4.0) with bone metastatic disease completed an exercise program for 12 wk. We assessed traditional metrics of adherence (attendance and loss to follow-up), in addition to novel proposed metrics (exercise-relative dose intensity, dose modification, and exercise interruption). Total training volume in kilograms (repetitions × sets × training load (weight)) was calculated for each patient. Results: Attendance assessed from traditional metrics was 79.5% ± 17.0% and four patients (9%) were lost to follow-up. The prescribed and actual cumulative total dose of resistance training was 139,886 ± 69,150 kg and 112,835 ± 83,499 kg, respectively, with a mean exercise-relative dose intensity of 77.4% ± 16.6% (range: 19.4%–99.4%). Resistance training was missed (1–2 consecutive sessions) or interrupted (missed ≥3 consecutive sessions) in 41 (87%) and 24 (51%) participants, respectively. Training dose was modified (reduction in sets, repetitions, or weight) in 40 (85%) of patients. Importantly, using attendance as a traditional metric of adherence, these sessions would have all counted as adherence to the protocol. Conclusions: Traditional reporting metrics of resistance training exercise oncology may overestimate exercise adherence. Our proposed metrics to capture resistance training dose, adherence, and tolerance may have important applications for future studies and clinical practice. Key Words: EXERCISE-RELATIVE DOSE INTENSITY, EXERCISE INTERRUPTION, DOSE MODIFICATION, WEIGHT TRAINING

Address for correspondence: Professor Daniel Galvão, Ph.D., F.A.C.S.M., Exercise Medicine Research Institute, Edith Cowan University, 270 Joondalup Drive, Joondalup WA 6027 AUSTRALIA; E-mail: d.galvao@ecu.edu.au. C.M.F. and T.S.N. made equal contribution to the article. Submitted for publication May 2019. Accepted for publication July 2019. Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal’s Web site (www.acsm-msse.org).

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As the field of exercise oncology is rapidly expanding, exercise has been increasingly recognized as an important therapeutic intervention to combat several cancer- and treatment-related adverse effects (1–5). There is a plethora of evidence highlighting the benefits of resistance training (RT) in this regard (2,4–9). Despite the promise of RT within exercise oncology, recent literature has highlighted improving the training prescription as central for progress in this area to continue (10). To improve prescription, it is important to examine how training variables (i.e., volume, intensity, frequency, type, and duration) and key principles (individualization, progressive overload, and specificity) are used within the current literature, but authors have often neglected to report these details (11,12). Further, several systematic reviews have demonstrated the consistent underreporting regarding the specifics of RT variables in clinical interventions (13–16), which significantly limits the applicability of findings and hinders the ability to progress in the design of precise interventions. Further, RT variables should be sequenced in a manner which aims to maximize specific outcomes of interest (i.e., periodization) (12); however, this is rarely the case in exercise oncology, possibly leading to a lower magnitude of benefit.

Despite underwhelming reporting of specific training variables, several reporting guides for clinical exercise interventions do exist, such as the CONSORT statement (17) and Consensus on Exercise Reporting Template (CERT) (18). The CERT provides guidelines for reporting the dosage of prescribed exercise using number of sets, repetitions, and duration (18). However, authors usually provide a range rather than exact numbers of these variables (i.e., three to five sets of 8–12 repetitions) making it difficult to quantify metrics such as total volume load (sets × repetitions × weight lifted) in which precise numbers are needed. Further, “adherence” to a program is typically defined as attendance (i.e., whether or not an individual shows up to a session), which gives little insight into the actual dose of exercise received by participants (i.e., number, type, and reasons for deviations from the prescribed dose). In fact, the “actual dose” more accurately reflects the adherence to a protocol as the extent to which an individual adheres to the prescribed program (set, repetitions, load, etc.). Without these details, particularly the dose of exercise that was actually achieved rather than prescribed, results could lead to over reporting of actual dose of RT completed. Therefore, current reporting standards may be insufficient to capture the necessary detail and true nuances of RT prescription. Recently, Nilsen et al. (19) presented a novel method for reporting exercise dose and adherence specific to aerobic training. The purpose of this study was to investigate the reported dose, adherence, and tolerance of RT from a recent trial in individuals with advanced prostate cancer. Details of inclusion criteria and recruitment have been previously reported (20). After study completion and posttest assessment, the usual care group was invited to perform the same exercise program prescription and assessments. Data contributed by these additional patients were pooled to extend the number of assessable patients with data on RT. The flow of participants through the study can be found in Figure 1. The study was approved by the University Human Research Ethics Committee, and all patients provided written informed consent.

### Exercise Program

The RT component of this program has been previously described in detail (20,21). Briefly, six resistance exercises that targeted the major upper- and lower-body muscle groups and were part of modular multi-modal exercise program were performed thrice weekly for 12 wks and supervised by an exercise physiologist. The exercise selection was modified based on the location and extent of bone metastases to avoid loading skeletal bone lesions as previously described and used in prior research in this population (20). Specifically, the core exercises included leg press, leg extension, leg curl, chest press, seated row, and triceps pulldown. Exercise modifications or substitutions were required based on the location and extent of metastases. Modifications included substituting an exercise with another that did not load the specific site (for example, leg press was avoided for individuals with bone metastases in the pelvic region), or unilateral limb loading of the region unaffected by bone metastases (if metastases were present in left femur, individuals were encouraged to perform unilateral knee extension/flexion with right limb). In the instance of extensive metastases, this resulted in avoidance of multiple exercises. For more information on the modular aspects of the exercise prescription, readers are directed to previous publications detailing this approach (20,21).

The RT program was designed to progress from lighter resistance and more repetitions to heavier resistance and fewer repetitions using 12 to 8 repetitions for two to four sets per exercise (Table 1). Load (kg) was increased using 5% to 10% increments for the next set or training session if the patient was able to perform more repetitions than the repetition maximum (RM) specified during a given set. Any modification to the exercise prescription (exercise selection, altering sets, and/or repetitions) was undertaken at the discretion of the supervising exercise physiologist.

### Volume metrics

Prescribed training volume and completed training volume (sets × repetitions × load) was calculated for each individual exercise, summed to provide a total session volume. Further, total volume from all sessions was summed to derive both the total prescribed and actual cumulative volume per patient. Exercise-relative dose intensity (ExRDI) was also calculated and was defined as the ratio of total actual to total prescribed cumulative dose, expressed as a percentage. An ExRDI of 100% indicates that a patient was able to perform the RT prescription, without dose modification, whereas an ExRDI of 70% would indicate that a patient required some sort of dose modification (reduction in sets, repetitions or weight) by 30% of the prescribed dose.

### METHODS

#### Participants

This is a follow-up analysis using data from a prior two-arm, randomized controlled trial to assess the effect of exercise compared with usual care in individuals with advanced prostate cancer. Details of inclusion criteria and recruitment have been previously reported (20). After study completion and posttest assessment, the usual care group was invited to perform the same exercise program prescription and assessments. Data contributed by these additional patients were pooled to extend the number of assessable patients with data on RT. The flow of participants through the study can be found in Figure 1. The study was approved by the University Human Research Ethics Committee, and all patients provided written informed consent.

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**Table 1**

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Sets</th>
<th>Repetitions</th>
<th>Load (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg press</td>
<td>3</td>
<td>12</td>
<td>70</td>
</tr>
<tr>
<td>Leg extension</td>
<td>3</td>
<td>12</td>
<td>60</td>
</tr>
<tr>
<td>Leg curl</td>
<td>3</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>Chest press</td>
<td>3</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>Seated row</td>
<td>3</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>Triceps pulldown</td>
<td>3</td>
<td>12</td>
<td>20</td>
</tr>
</tbody>
</table>
Dose modification quantification. Attendance was quantified as a percentage of how many total sessions a participant attended, regardless of how much training was completed during the session. We defined adherence outcomes as proposed in previous research (19): missing session defined as missing single or two consecutive sessions; exercise interruption defined as missing three or more consecutive exercise sessions; and permanent exercise discontinuation defined as the permanent discontinuation of exercise before week 12. Further, loss to follow-up (i.e., participants with baseline data but no data for postintervention assessment) was also recorded. Session dose modification was defined as any session requiring the prescribed dose (number of set and/or repetitions and/or training load reduced) to be modified during the session. Dose escalation was defined as any session where dose was modified to progress individuals (i.e., load was higher than initially prescribed).

Metrics are presented as the number and percentage of patients requiring at least one of the above-presented criteria, and number and percentage of sessions that met the above described criteria. This information was also collated to garner information on adherence per session, per patient, and per exercise.

Statistical Analysis

Descriptive statistics (mean ± SD and frequencies) were used for baseline characteristics. Dose and tolerability variables for RT were summarized by mean (SD and range, where appropriate), including all patients who initiated the exercise intervention program. A paired sample t test was used to determine the difference between planned and actual cumulative RT dose. Descriptive statistics were calculated using Microsoft Excel (2016) with other analyses conducted using SPSS (version 22.0, IBM, Chicago, IL).

RESULTS

Patient characteristics are presented in Table 2. Patients were age 70.15 ± 8.90 yr and presented with extensive metastatic...
lesions in the pelvis (77.3%), femur (36.4%), rib/thoracic vertebrae (61.4%), lumbar vertebrae (38.6%), humerus (18.2%), and other sites (65.9%). Ninety-three percent of patients were undertaking androgen deprivation therapy.

Conventional Attendance Metrics

Using conventional metrics, training session attendance was 79.5% (range, 19.4%–100%) Four participants were lost to follow-up due to increased bone pain (n = 2), health deterioration (n = 1), or a fall at home (n = 1).

Exercise Dose Quantification and Adherence Metrics

The prescribed total cumulative exercise dose across the intervention was 139,886 ± 69,150 kg (range, 7872–300,546 kg) (Fig. 2A), which yielded a mean weekly training volume of 3886 ± 37 kg (range: 2062–4848 kg). The completed cumulative total exercise dose across the intervention was 112,835 ± 83,499 kg (range: 7104–240,788 kg) (Fig. 2A). There was a statistically significant difference between the prescribed and completed cumulative dose (P = <0.001).

The prescribed and completed training volume per session is depicted in Figure 2B. The ExRDI was 77.4% ± 16.6% (range: 19.3%–99.4%) (Fig. 2C), indicating that the dose was modified/interrupted for ~22.6% of the sessions.

The dose was interrupted in 24 (51%) of the participants due to a variety of health-related (e.g., general illness, treatment related pain, etc.) and non-health related (e.g., vacation) reasons (Table 3). Forty-four patients (87%) missed one or more exercise sessions during the intervention, with most missed sessions due to conflicting appointments and general illness. The dose was modified in 41 (87%) of patients and 149 (9%) of sessions. Specifically, dose was modified via the reduction in load (n = 79; 53%), reduction in sets (n = 19; 13%), repetitions (n = 9; 6%), different exercise selection (n = 2; 1%) or exercise removal (n = 38; 25%). Dose was modified for a variety of health-related (n = 94; 5%) and non-health-related reasons (e.g., time-constraints, equipment availability, previously missed session) (n = 55; 3%). On the other hand, dose escalation occurred in 19 (40%) of the patients. Adjustments were undertaken by exercise physiologists to ensure an appropriate load was assigned, and the principle of progressive overload was followed. Additionally, adherence per patient is presented in Figure 3A, and adherence per exercise in Figure 3B.
across the cancer spectrum and intervention time course, as will the reasons for these interruptions/modifications (22). For example, having to substitute or modify upper body RT exercises (i.e., incorporating physical therapy exercises for postsurgery, rather than traditional RT exercises) in women with breast cancer as a result of treatment-related dysfunction could potentially explain reasons why limited or no improvements were seen in upper body strength (23). Another example could be individuals with head and neck cancer undergoing chemotherapy and/or radiotherapy who need consistent dose reductions as a result of low energy from malnutrition or other acute treatment toxicities (24).

This process of dose modification essentially refers to the concept of autoregulation, where the training stimulus is modified in accordance with an individual’s “readiness to train.” In this sense, subjective/objective measure of sleep, fatigue, energy, recovery (or other relevant indices) can be used to provide an individualized, appropriate training stimulus (12,23). Further, it has been posited that the flexibility of autoregulation within a periodized program may help ward off staleness, improve enjoyment, and ultimately foster the long-term maintenance of activity (12). Irrespective, reporting dose modifications via exercise selection in these circumstances can lend further insight into the feasibility of delivering an exercise intervention during periods of illness, dysfunction, or transient toxicity, which provides important information for practitioners to understand the expectations and challenges of working with specific populations.

Implementing traditional metrics, outlined by Nilsen et al. (19), of adherence in exercise trials, such as loss to follow-up and session attendance alone, have limited utility because they may lack breadth and specificity that is critical to defining adherence and tolerance of the RT dose prescribed in the intervention. For example, Scott et al. (22) reported that some type

![FIGURE 2](image)

**FIGURE 2**—Data are mean ± SD. Prescribed vs actual cumulative training volume (A) and mean training volume per session (B) ([Green colored bars](#) indicate prescribed dose, whereas [red colored bars](#) indicate actual or completed dose.); ExRDI per session across the intervention (C).
TABLE 3. Reasons for dose modifications.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
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<tr>
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<td>Increased bone pain</td>
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<td>5</td>
<td>23</td>
<td>2</td>
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<tr>
<td>Health deterioration</td>
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<td>3</td>
<td>28</td>
<td>2</td>
</tr>
<tr>
<td>Fall at home</td>
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<td>3</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
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<td>51</td>
<td>154</td>
<td>9</td>
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<tr>
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<tr>
<td>General illness</td>
<td>6</td>
<td>13</td>
<td>25</td>
<td>1</td>
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<td>Treatment-related pain</td>
<td>2</td>
<td>4</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>Conflicting appointments</td>
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<td>9</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Fatigue</td>
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<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Nausea</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Non-health-related</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Vacation</td>
<td>15</td>
<td>32</td>
<td>96</td>
<td>9</td>
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<td>Conflicting appointments</td>
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<td>5</td>
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<td>General illness</td>
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<td>16</td>
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<tr>
<td>Fatigue</td>
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<td>9</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Nausea</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>0</td>
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<tr>
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<td></td>
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<tr>
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<td>15</td>
<td>1</td>
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<td>1</td>
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<td>Dose modifications</td>
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<td>149</td>
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<tr>
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<td></td>
<td></td>
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<tr>
<td>Fatigue</td>
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<tr>
<td>Lower extremity pain</td>
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<td>23</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Bone pain</td>
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</tr>
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<td>Nausea</td>
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<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
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<td></td>
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<tr>
<td>Dose escalation</td>
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<td>40</td>
<td>38</td>
<td>2</td>
</tr>
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</table>

Definitions: permanent discontinuation: permanent discontinuation of exercise prior to week 12; exercise interruption: missing ≥3 consecutive supervised sessions; missing session: missing single or 2 consecutive sessions; dose modification: ≥1 session required dose modification, and the total number of sessions requiring a dose reduction; dose escalation: any session where dose was modified to progress individuals (i.e., load was higher than initially prescribed).

aNumber of reasons for dose modification sums to greater than the total number of patients listed since several patients required dose modification for different reasons.

bOther: time constraints, equipment availability, previously missed session.

dose of dose modification and early session termination occurred in 49% and 36% of all training sessions, respectively in their trial; however, conventional metrics would have classified the modified and terminated sessions as 100% adherence. Clearly, this traditional metric limitation highlights the need to calculate adherence in a more precise manner. Specifically, if sessions in which dose modification occurs are counted as 100% attendance then this does not provide an accurate picture of the participant’s feasibility and tolerability of exercise, particularly in advanced cancers or periods of intense cancer treatments, highlighted by almost half of the sessions in the study by Scott et al. (22) being modified in some way. Consequently, adaptations may be compromised when exercise dosage is decreased. For example, Scott et al. (22) had a predetermined feasibility threshold set at an ExRDI of 70%, the authors reported that individuals who did not meet this threshold experienced an 11% decline in peak oxygen consumption whereas those with an acceptable feasibility (ExRDI ≥ 70%) experienced a significant improvement in cardiorespiratory fitness (22). Ultimately, it seems clear that altering a training session dose can affect study outcomes, and this should be considered when examining the feasibility of exercise interventions in various cancer populations, and should impact training recommendations in practice.

Importantly, simply using ExRDI (and other metrics) only addresses reporting and not the quality of an intervention. The CONSORT and CERT statements provide excellent frameworks for the reporting of randomized controlled trial components. However, the specifics of these guidelines are open to interpretation and can be limited when it comes to capturing the complexity of RT dose received, as noted by several systematic reviews, which demonstrated that RT intervention characteristics remain consistently underreported (13–16). Thus, the methods of reporting adherence outlined in this article should be utilized in parallel with the reporting guidelines outlined by CONSORT or CERT (18). Ultimately, the applicability of exercise is medicine, and the investigation of exercise dose–response on several clinical endpoints becomes irrelevant, unless there are accurate metrics in place to quantify the actual dosage undertaken by the patient. Combining ExRDI with appropriate reporting of intervention characteristics will allow for more accurate description of the dose of exercise prescribed and tolerability of that dose. Subsequently, this will allow for greater insight into the tolerability of exercise, ability to better compare exercise dose across different populations and provide a more specific framework for exercise prescription and modification.

RT prescription is complex, with many variables that can be manipulated (exercises, sets, repetitions, load, rest period, time under tension, etc.). Consequently, there is unlikely to be a consensus on a gold-standard method to quantify RT load, and choice of method will be a combination of population studied, reason for use, and feasibility. For example, methods to quantify volume from machine, dumbbell or free weights are likely to be different than those from plyometric exercises or resistance bands and should be tracked separately. Additionally, calculating volume load with group-based circuit training or home training may be difficult and impractical. Additionally, tracking relative volume (i.e., sets × repetitions × percentage of one-repetition maximum) as opposed to absolute (sets × repetitions × load) would add a greater degree of accuracy in accounting for individual strength levels and offering further insight into the magnitude of progression. Nevertheless, we contend that the calculation of volume load is a simple and quick method that can allow for better monitoring, adjusting, and reporting of the RT prescription (25).

It is important to note that traditional metrics, such as attendance and loss-to-follow up, are not without value. For example, from a behavioral perspective, regular attendance at exercise sessions/programs may demonstrate that an individual has developed the self-regulatory skills to set a goal of participating in an exercise session and translated that intention/goal into action by enacting a plan and overcoming barriers that could have impeded attendance (26–31). Consequently, attendance and loss
to follow-up (i.e., retention) may offer value and insight into the
efficacy of an intervention aimed at behavior change. Ulti-
mately, combining these metrics will allow for an expansion
of attendance and provide both breadth and specificity in future
interventions evaluating elements of an exercise intervention,
such as adherence, dose, and tolerance.

Notably, the proposed metrics may also be applied to other
populations where the exercise dose might require modifica-
tions to accommodate comorbidities or conditions (e.g. chronic
obstructive pulmonary disease, knee osteoarthritis or diabetes).
We have included a master template (see Supplemental Digital
Content 1, master template for calculating RT dose metrics,
http://links.lww.com/MSS/B719) that can be adapted to other
RT interventions to assist researchers/practitioners looking to
adopt these metrics. In summary, previously described methods
for reporting aerobic exercise interventions in cancer can be
adapted to provide valuable information on the tolerability and
adherence to RT in exercise interventions for cancer patients.

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in Prostate Cancer Survivorship.

The sponsors did not participate in the design or conduct of the
study; collection, management, analysis, and interpretation of the data;
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falsification, or inappropriate data manipulation. The results of the pres-
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C. M. F., T. S. N., and D. G. each had full access to all the data in the
study and take responsibility for the integrity of the data and the accu-
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