Chapter

Muscle Health: The Gateway to Population Health Management

Thomas Gilliam and Paul Terpeluk

Abstract

The muscle on your frame is a prime indicator of health and longevity. Dr. Paul Terpeluk with the Cleveland Clinic has stated that muscular strength is the new vital sign of workplace health and safety. Research studies focusing on Type II diabetes, cardiovascular disease, musculo-skeletal injuries, certain cancers and the delay of dementia have shown a strong correlation between disease prevention and muscular strength. IPCS' database of over 500,000 strength tests have shown a workers' absolute strength today is at least 14% weaker than the worker 15 years ago and weighs about 8 pounds more. Over the last 10 years, there has been a significant shift by 52% with an increase in the number of workers with a BMI of 35 or greater. The Cleveland Clinic implemented a new hire muscular strength assessment to place new hire applicants into jobs that match their physical capability in 2011. The outcomes show a statistically significant reduction in number of employee health, pharmacy and workers' compensation claims and costs with overall savings near $25 million. Musculo-skeletal health of the worker can be improved. When a worker maintains good muscular strength, the worker is more productive, has fewer medical claims and workers' compensation claims.

Keywords: muscle health, muscle strength, musculo-skeletal, disease prevention, cost savings

1. Introduction

Population Health continues to expand especially as new research demonstrates ways to better manage a person's health. One area of interest is the impact muscle has on enhancing health and disease prevention [1–12]. A healthy and strong muscle mass increases the chance of better managing and preventing certain diseases such as Type II diabetes, cardiovascular disease, certain cancers, dementia and hypertension to name a few [3–5]. A healthy muscle mass also helps in maintaining a healthier body weight, the ability to sustain an adequate overall body metabolism with age and an enhanced immune system to help fight off various viruses and disease [6, 8, 9]. Muscular strength with aging puts individuals at greater risk for sarcopenia (loss of muscle) not only for the diseases already mentioned by also for slips, falls, functionality and frailty [4, 11–12].

2. Research general

In 2006, Wolfe discussed the underappreciated role of muscle in health and disease [1]. He discussed the importance of future research to include factors related to muscle mass, strength and metabolic syndrome. Wolfe focused on the importance of muscle protein and the pool of amino acids in maintaining a relatively constant plasma glucose concentration. He also discussed the role muscle plays in obesity and Type II diabetes. Argiles and associates in 2016 supports Wolfe's research on the importance of muscle regulating protein metabolism throughout the body [4]. Both of these studies strongly support maintaining a healthy and strong muscle mass throughout one's lifespan especially to prevent sarcopenia and certain diseases. This was further emphasized by Mrowka and Westphal in their article on "skeletal muscle in the fight against chronic disease" published in 2018 [5]. DeCarvalho and associates showed an inverse relationship between skeletal muscle mass adjusted for weight and BMI with metabolic syndrome in both males and females [2]. Their study researched 689 adults between the ages of 20–59. Mesinovic and associates discussed the connection between sarcopenia and Type II diabetes [10]. The loss of muscle alters glucose uptake in the muscle leading to more glucose in the blood which increases the risk of Type II diabetes.

2.1 Research sarcopenia

Sarcopenia is a critical concern not just because of the loss of muscle and its ability to fight disease and infection, but because the individual is at greater risk for slips, falls and injury [4, 11–16]. If not remedied, the loss of muscle can lead to a frail state which can be fatal [4]. Every day functionality and daily activities become more difficult to perform with the loss of muscle. Muscle protein breaks down and rebuilds daily. Sarcopenia can start as early age of 25 and accelerates after age 60 years and sometimes sooner. The inability to rebuild muscle protein as the body ages contributes to sarcopenia. It should be noted that as the body loses muscle, the loss of muscle strength (dynapenia) occurs more rapidly. It also should be noted that obese individuals are at greater risk for sarcopenia.

2.2 Research inflammation

Inflammation is associated with most chronic diseases [8, 9, 17]. There is compelling evidence that shows physical activity to include strength training offers a defense to chronic diseases. David Nieman discussed the link between physical activity and the body's immune system [9]. While there is compelling evidence to suggest that physical exercise will enhance the body's immune system, there is also evidence that suggests lengthy, intense workout sessions might be harmful to the body's immune system. Nieman suggests physical activity workouts should be no more than 60-minutes at a moderate-vigorous intensity to safely enhance the immune system [9].

2.3 Research cancer

One area of research that has increased dramatically focuses on muscle mass and strength related to cancer treatment and prevention [18–28]. Caan and associates in 2018 showed that women with non-metastatic breast cancer had 41% better chance of surviving with a healthier muscle mass compared to sarcopenic non-metastatic breast cancer patients [18]. The American College of Sports Medicine (ACSM) has published research showing the impact physical activity has in lowering the risk of at least 7 different cancers and increasing survivability [22–24, 26, 27]. ACSM recommends a variety of physical activities to include resistance training (strength), aerobic and balance with options for light, moderate or vigorous intensity. The

ACSM and the National Academy of Sports Medicine certify health and exercise professionals to work directly with cancer patients to improve their strength and muscle mass.

2.4 Research mortality

There is evidence demonstrating muscular strength as a predictor of mortality in a healthy population [29–34]. A meta-analysis by Garcia-Hermosa and colleagues show that individuals with good upper body and lower body strength have lower risk of mortality regardless of age [29]. ACSM has published numerous research studies demonstrating the effectiveness of resistance training on health for individuals from 15 to 90 plus years old [22–24, 26, 27]. Moberg recently published data about the significance of a "muscle memory" found in each myonucleous [30]. This study focused on how much impact does resistance training when done earlier in life has on muscle later in life. It appears that if resistance training was done earlier in life that your muscle will *retrain faster* in terms of regaining strength compared to if you are just beginning. The research is new and so there are many unanswered questions such as how much faster will strength return, will it return to previous strength levels and how long does the "muscle memory" retain previous strength levels? But the research also shows that it is never too late in life to reap the benefits of resistance training. Research shows the human body is able increase strength levels at any age – even those individuals in their 80's and 90's [22–24, 26, 27]. This is extremely important in preventing sarcopenia which can lead to frailty as well as cachexia which occurs with some diseases such as cancer [4, 28].

2.5 Research industrial worker

Despite the incredible abundance of research showing how a healthy muscle mass leads to a healthier lifestyle, the worker today in general is weaker and heavier than the worker 25 years ago. One reason for this is that physical demands of many jobs have been decreased due to robots and other ergonomic assists [35, 36]. Automation is good, especially in industry. It contributes to a safer workplace. But automation greatly diminishes the physical demands of the job which has impacted the overall health of the industrial worker.

Since 1960, the percentage of moderate intensity physically demanding jobs in the United States has decreased from about 50% to 20% in 2010, but the light intensity jobs have increased from 38% to about 55% [35]. Sedentary jobs increased as well from 15–22%. Most of these changes took place because of automation. This means the amount of physical work done by today's worker has greatly diminished.

Unfortunately, the less physically active the worker becomes, the greater the risk for injury and certain diseases. Some of this increased risk occurs because of an increase in body weight (fat weight) tied to the loss of muscle mass and strength.

3. IPCS

Industrial Physical Capability Services, Inc. (dba IPCS) performs muscular strength assessments for industry in the United States using isokinetic equipment for shoulder and knee flexion and extension at 60 degrees per second [37, 38]. Between 2005 and 2019, 406,731 strength tests were completed (327,913 males and 78,818 females). To compare changes in muscular strength, an analysis was made comparing the year 2005 to 2019 (a 15-year span).

Descriptive data for males and females (Means ± SD)						
	Female			Male		
	2005	**2019**	**Kolmogorov–Smirnov Test**	**2005**	**2019**	**Kolmogorov–Smirnov Test**
Age (yrs)	34.1 ± 10.34	33.8 ± 11.72	>.001	34.0 ± 10.34	34.1 ± 11.63	>.001
Height (in)	64.8 ± 2.94	64.3 ± 64.34	<.001	70.3 ± 2.99	71.0 ± 3.03	<.001
Weight (lbs)	167.8 ± 41.48	177.3 ± 47.92	<.001	205 ± 44.01	207.6 ± 49.50	<.001
BMI	28.1 ± 6.65	30.1 ± 7.59	<.001	29.1 ± 5.66	29.8 ± 6.57	<.001
Sample Size	2637	6701		23,274	13,219	

Table 1.
Physical characteristics and sample size (mean ± SD).

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Knee and shoulder strength measures for males and females (Means ± SD)						
	Female			Male		
Absolute Strength	**2005**	**2019**	**Kolmogorov–Smirnov Test**	**2005**	**2019**	**Kolmogorov–Smirnov Test**
Shoulder (ft. pds)	102 ± 26.32	90 ± 25.74	<.001	189 ± 43.26	170 ± 43.27	<.001
Knee (ft. pds)	246 ± 81.76	235 ± 76.50	<.001	388 ± 89.23	347 ± 91.69	<.001

Table 2.
Absolute strength measures for the knee and shoulders (means ± SD).

Table 1 shows the physical characteristics of those new hire industrial applicants tested in 2005 compared to 2019 based on gender. Due to unequal sample sizes and unequal variances, the Kolmogorov–Smirnov Test was used to test for significance within gender between 2005 and 2019. There was no significant difference for age (>.001) within gender between 2005 and 2019. Height, weight and BMI was significantly different within gender between the two time periods. The female body weight increased most between 2005 and 2019 (+9.5 pounds). The BMI increased for both genders.

Changes in the absolute strength of the shoulder and knee flexors and extensors of the worker by age group between 2005 and 2019 is shown in **Table 2**. The absolute shoulder strength and knee strength decreased significantly (<.001) between 2005 and 2019 for males and females.

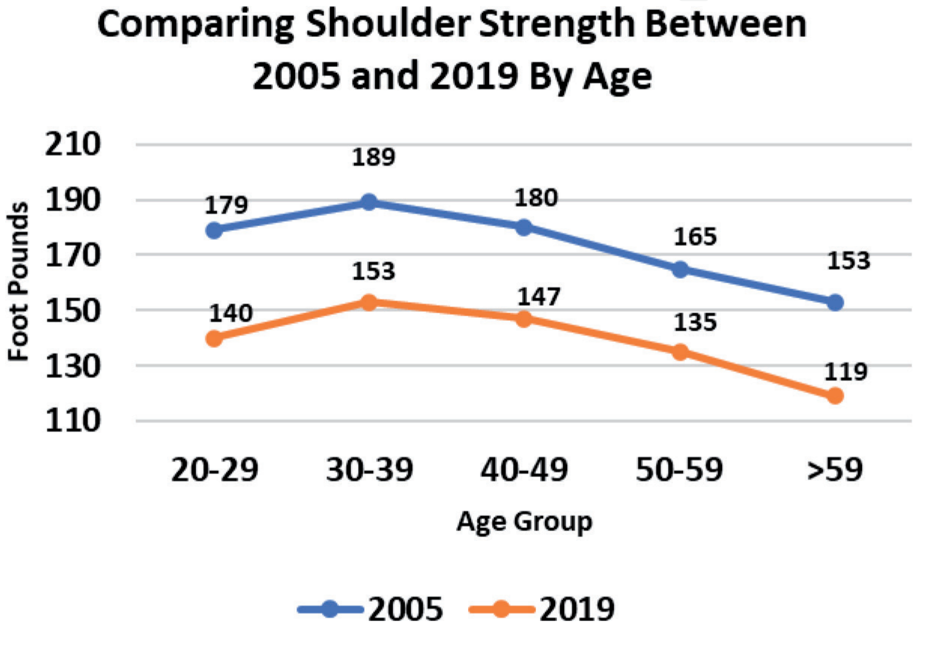

Figure 1.
Changes in absolute shoulder strength (ft. pds.) of the worker by age group.

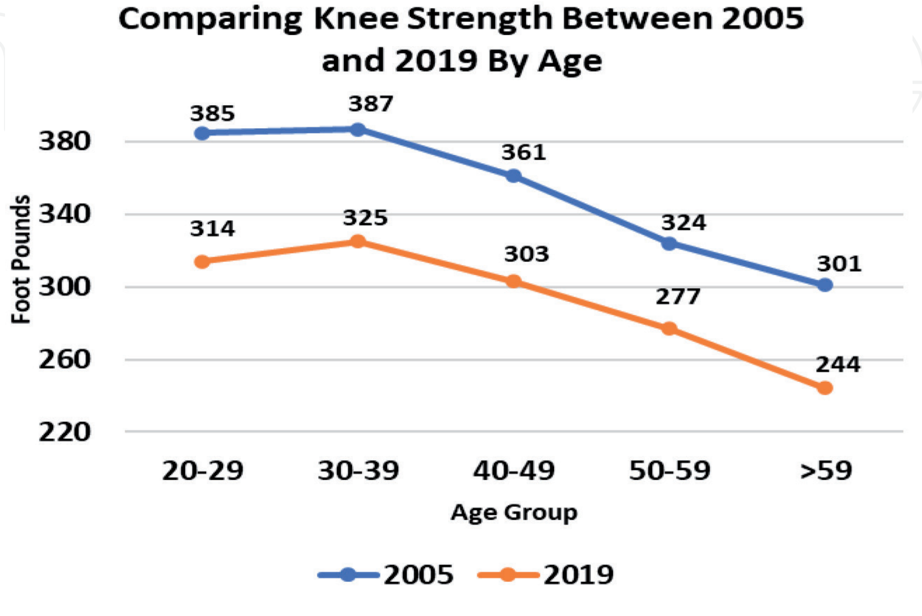

Figure 2.
Changes in absolute knee strength (ft. pds.) of the worker by age group.

Changes in the absolute strength of the shoulder and knee flexors and extensors of the worker by age group between 2005 and 2019 are shown in **Figures 1** and **2**, respectively.

Figure 1 shows for each age group that the shoulder strength is anywhere from 14.5% to 18.9% weaker in 2019 compared to 2005.

Figure 2 shows for each age group the absolute knee strength is anywhere from 18.2% to 22.2% weaker in 2019 compared to 2005. Both **Figures 1** and **2** show substantial difference in the strength of the worker between 2005 and 2019. **Figure 3** shows the differences between years by age groups as a percent change.

The first three figures show the absolute shoulder and knee strength has decreased on average by 18% across all age groups between 2005 and 2019. The figures also show after the 40–49 age group there is a rapid decrease in absolute

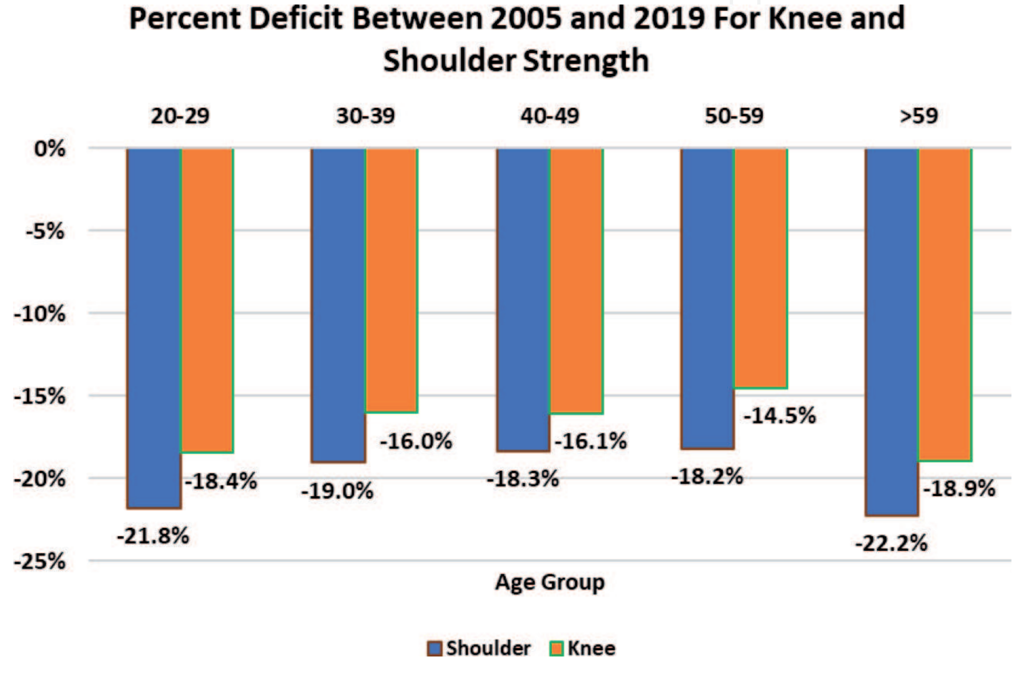

Figure 3.
Percent deficit in shoulder and knee strength between 2005 and 2019.

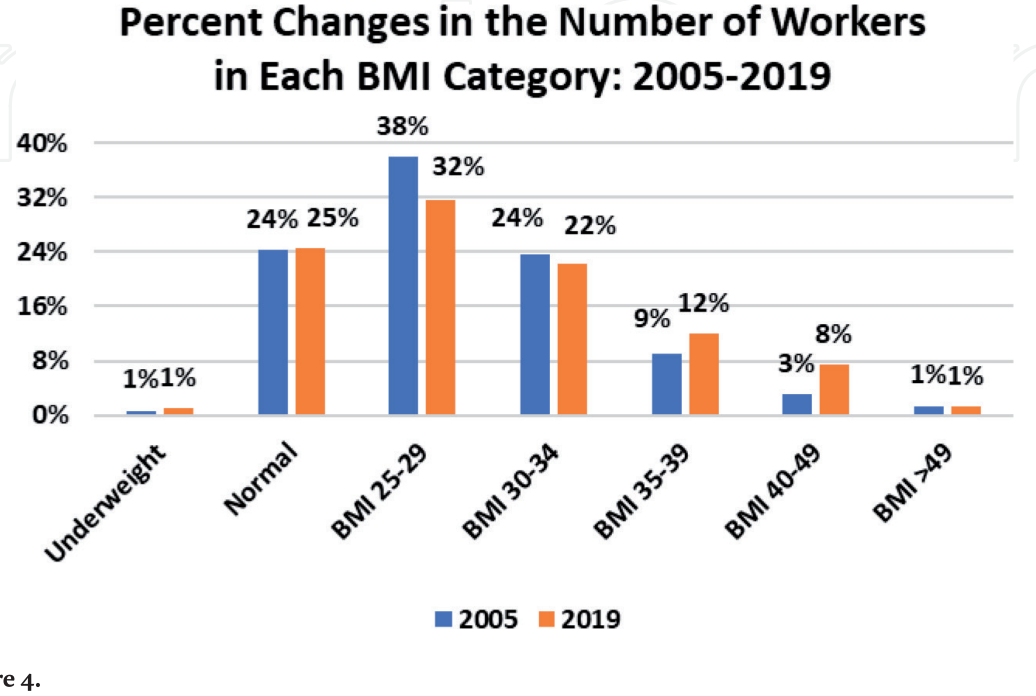

Figure 4.
Percent changes in number of Workers for each BMI category.

strength which supports the concept of loss of muscle mass and strength with aging along with an increase in sedentary lifestyles. Interestingly, the youngest age group (20–29) had the greatest deficit for the shoulder and knee strength when compared to the three age groups between 30 and 59. This is a reflection on the sedentary lifestyles found in children and youth which then carries over into industry.

During the IPCS testing process, height (in) and weight (pds) are measured. For research purposes IPCS calculates Body Mass Index (BMI) to monitor trends in obesity within the workplace. **Figure 4** compares the changes in the percent number of workers in each BMI category from 2005 to 2019. IPCS looks at changes in BMI for the category 50 or more or extreme morbid obesity. When comparing 2005 to 2019, the overweight category (BMI 25–30) decreased from 38–32% whereas the BMI categories equal to severe obesity (BMI 35 or more) and greater increased from 13.6% to 20.7% which represents a 52.2% increase. It is these higher BMI categories associated with an increase in certain diseases such as Type II diabetes, hypertension and cardiovascular disease. Further, work by Ostebye in 2007 has shown that those workers with a BMI of 35 or more have 2 times the number of soft tissue injuries, 7 times the workers' compensation costs and 13 times more lost work days [39].

4. Research study Cleveland clinic

IPCS has been involved providing a comprehensive strength screening evaluation for the new hires for the Cleveland Clinic since January 2011 [40]. This has resulted in the collection of new hire data related to strength and medical claims which have been studied from 2011 through 2017.

4.1 Research study design

This quasi-experimental, non-randomized study was conducted at Cleveland Clinic in northeast Ohio. It was designed to assess the impact of a strength screening assessment for nurses used at the time of hire, and compare the difference in health plan costs to newly employed nurses who did not receive the strength screening. Participants were identified from the applicant pool as part of the new hire process from January 2008 through December 2017. Applicants were either registered nurses, licensed vocational nurses, licensed practical nurses, or patient care nursing assistants applying for a nursing position in any unit of the hospital. The interviewing process for potential candidates consisted of an online application, followed by a phone interview and then an in-person interview if warranted. Nurses that passed these initial requirements for selection were then scheduled for a physical exam and a drug screen. A strength assessment screening was added to the existing hiring protocol as the last segment of the interview process for nurses hired from January 2011 through December 2017.

Nurses hired in January 2008 through December 2010, prior to the strength assessment screening implementation, served as a Historical Comparison Group. There were no significant environmental or business practice changes observed during this time period from January 2008 through December 2017, and health plan coverage did not change across the two time frames. The only difference in the selection process in 2011–2017 compared to 2008–2010 was the addition of the physical capability evaluation (PCE™). The project was overseen by hospital administrators, and conducted based on quality improvement protocols. Given that this was a retrospective analysis of a hiring practice policy, and not a formal research study, Institutional Review Board approval or research consent was not required.

The strength screening was conducted through an objective physical capability evaluation (PCE™). The PCE is designed to measure the applicant's isokinetic force generating capability (strength) of muscle groups based on the outcomes of a defensible job task analysis (JTA) [37]. The JTA was conducted according to guidelines of the Americans with Disabilities Act of 1990 (ADA) to determine the skills necessary to safely and effectively perform the essential functions associated with the nursing duties (e.g., lifting, carrying, bending, stooping, climbing, etc.). These validation studies were used to identify appropriate cut-off scores using the U.S. Department of Labor strength definitions for medium, heavy and very heavy job tasks [41]. It was determined that the "target score" for the nursing job category would be set at the medium strength level. The results of the JTA indicated that movement patterns of the major muscle groups involved with shoulder flexion and extension and knee flexion and extension were critical to safely performing the essential functions of the nursing jobs.

The PCE testing was conducted in the Occupational Medicine department, in a controlled environment using isokinetic equipment and a standardized testing process (tested at 60 degrees per second, two sets of five repetitions flexion and extension for knees and shoulders) administered by trained professionals [38]. To improve reliability of the measure, health system physical therapists and athletic instructors were trained and observed for proper technique administering the PCE, verifying that they completed the evaluation correctly. PCE results were collected at the time of conducting the assessment, and submitted to a centralized database for data interpretation. These objective evaluations were then interpreted by IPCS (a third party company). The interpretation included isokinetic measurements through:

1. a force curve analysis in which the applicant's force curves generated were compared to an unmatched normative force curve derived from nearly 500,000 normative curves in the existing database;

2. a body muscle symmetry analysis which involved comparing the applicant's right and left shoulder and knee scores, agonist to antagonist muscle groups and upper and lower body scores to a normative database consisting of more than 500,000 normative symmetry scores;

3. assessing the applicant's strength to body weight ratio score.

The screening took approximately 30 minutes to complete per applicant.

PCE data were analyzed based on proprietary algorithms, and scores were electronically returned to Human Resources through summary reports [37]. An applicant was recommended for hire if the PCE strength screening score was equal to or greater than the "target score".

4.2 Research study data sources and analysis

Medical claims cost data for the first 12-months of employment were obtained for each annual cohort from the employer-sponsored health plan. The analyses include data for all newly hired nurses that have 12-months of continuous enrollment in the employer-sponsored health plan after their hire date.

Total annual and per employee per month (PEPM) paid medical costs were calculated for nurses hired in each of the three years prior to initiation of the PCE (2008–2010), as well as for nurses hired after the PCE program was initiated (2011–2017).

4.3 Research study results

Of the 16,113 nurses who were included in this study, 85% were females and 15% were males. There were no refusals to take the physical capability screening.

Table 3 shows the number of eligible nurses hired in each group. There were 2481 eligible nurses hired in 2008–2010 in the Historical Comparison Group, and 13,632 eligible nurses in the PCE Group. The total member months for the Historical Comparison Group was 15,788 months, and for the PCE™ Group the total was 34,102 as shown in **Table 3**.

Figure 5 shows what percent of the new hires had medical claims for each group. The Historical group had significantly higher percentage of claims for those hired (57.4%) compared to those hired in the PCE group (28.4%).

As shown in **Table 4**, the difference for Average Medical Paid and the PEPM between the Historical Comparison Group and the PCE™ Group is $882 and $77.07, respectively. Due to unequal sample sizes and unequal variances, the Kolmogorov–Smirnov Test was used to test for significance between the Historical Comparison Group and the PCE Group.

The costs to implement the PCE™ program for 2011–2017 were $1,192,672. To calculate the savings for medical claim costs, the average claim cost for Historical group was multiplied by the number of new hires for the PCE group (13,632) times the percentage of new hire applicants that had a claim for the Historical group (57.4%) which is $22,519,682 (**Table 5**). The actual medical claim cost for the PCE group was $7,722,524. The combination of a smaller percentage of claims for the PCE group along with the lower average medical claim cost resulted in $14,797,158

	Historical group	PCE group
Number Hired	2481	13,632
Number Medical Claims	1425	3869
Number Member Months	15,788	34,102

Table 3.
The number of new hires, medical claims and member months for each group.

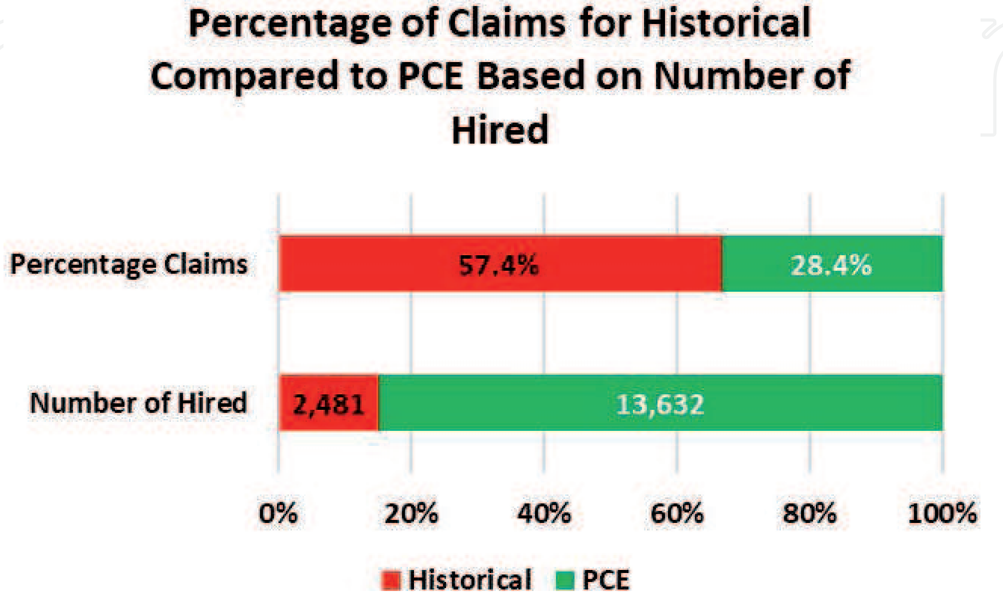

Figure 5.
Percentage of claims for each group based on number of new hires.

	Average Medical Claim Cost Mean ± SD	Per Empl Per Month Mean ± SD	Kolmogorov–Smirnov Test
Historical Group	$2878 ± 6930.73	$239.80 ± 577.49	<.001
PCE Group	$1996 ± 4836.42	$165.73 ± 399.53	<.001

Table 4.
Comparing average medical claim and PEPM costs between historical and PCE groups (means ± SD).

	Total Medical Costs
No PCE	$22,519,682
W/PCE	$7,722,524
Savings	$14,797,158

Table 5.
Total savings resulting from the PCE program.

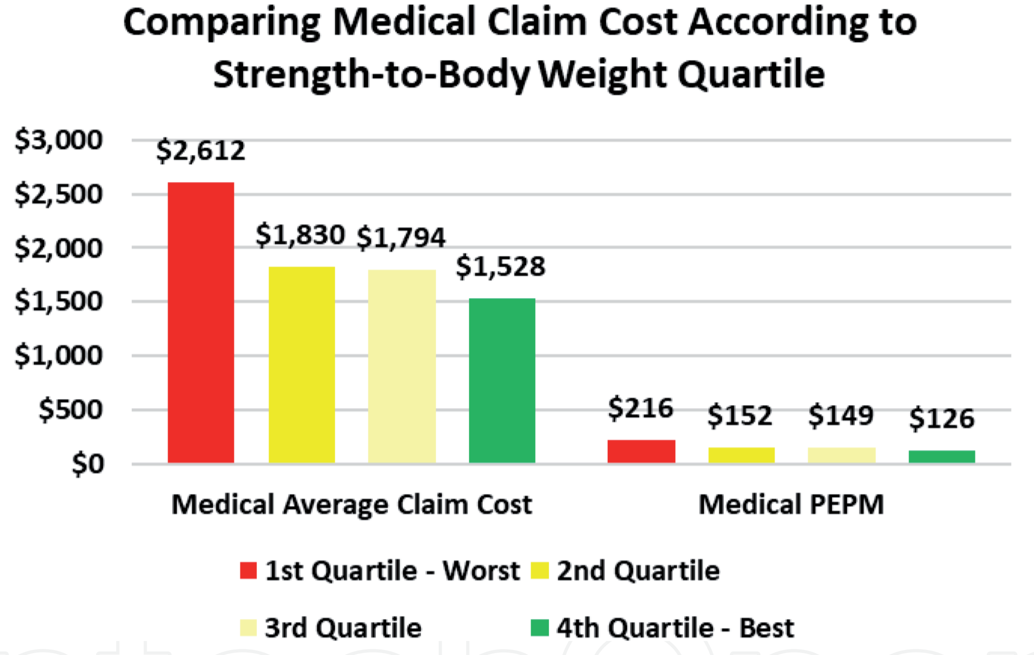

Figure 6.
Comparing medical claim costs for nurses based on quartile measures.

in savings between 2011 and 2017 (**Table 5**). The return on investment for the program was $12.41.

The combination of increased fat weight and loss of muscular strength results in a substantial decrease in the worker's strength to body weight ratio (SBW). (A worker's strength should be proportionate to his/her body weight.) It is clear that workers with a healthy strength to body weight ratio perform better, are safer and have fewer employee health claim costs. An analysis of the Cleveland Clinic SBW data shows that those nurses with the lower SBW scores (1st Quartile) medical costs were about 42% more compared to those nurses with a higher SBW score (4th Quartile) as shown in **Figure 6**. A non-parametric test computed the statistical differences between the four quartiles. A Kolmogorov–Smirnov Test was used to test for significance between the first and fourth quartile which was significant at the .001 level (**Figure 6**).

Those individuals in the lower quartile have either weak absolute strength and/or excess body weight compared to those who are in the upper quartile who have good absolute strength and a health body weight. The SBW is a good measure and predictor of health and injury risk. The SBW also shows the importance of maintain a healthy muscle mass and healthy body weight throughout life.

4.4 Research study conclusions

The Cleveland Clinic study shows that it is possible to design a defensible strength test to be used in the selection process for physically demanding nursing jobs. This study shows the importance of physical strength specifically in the nursing profession. When a nurse's physical capability is correctly matched to the physical demands of the job, a nurse can better meet the essential functions of the job and better serve patients. Also, the analysis of this study shows it is possible to hire through a work justified strength screening program a healthier worker who will have lower paid average medical and per employee per month costs in the first year of benefit eligibility. The results of this study support the premise that strength is a new vital sign of workplace health.

5. Conclusions

As automation continues to improve in the workplace and with fewer physically demanding jobs, the industrial worker will need to rely on means other than work to maintain a healthy and strong muscle mass. Without a resistance training intervention, the worker will continue to become weaker and heavier putting the worker at greater risk for injury and disease. This will lead to greater costs and absenteeism. How much of a responsibility will the employer have in providing such intervention programs remains to be seen. The intervention could be in short durations (10 minutes) several times a day at the workplace or providing some incentive to reimburse memberships at fitness centers. This is nothing new and it has not been very successful in the past. But making muscle health tied into a health/benefit deductible plan could improve participation rates in resistance training programs.

The research is now clear that muscle strength is the new vital sign of the worker's physical health. Musculo-skeletal health of the worker can be improved. When a worker maintains good muscular strength, the worker is more productive and has fewer medical claims.

Conflict of interest

The authors declare no conflicts of interest with respect to research, authorship and/or publication of this article.

Author details

Thomas Gilliam[1]* and Paul Terpeluk[2]

1 IPCS, Hudson, OH, USA

2 Cleveland Clinic, Cleveland, OH, USA

*Address all correspondence to: tgilliam@ipcs-inc.com

References

[1] Wolfe RR. The underappreciated role of muscle in health and disease. Am J Clin Nutr. 2006;84:475-82.

[2] Carvalho CJD, Longo GZ, Kakehasi AM, Pereira PF, Segheto, KJ, Juvanhol, LL, Ribeiro, AQ. Association between skeletal mass indices and metabolic syndrome in Brazilian adults. J Clinical Densitometry. 2020. DOI: 10.1016/j.jocd.2020.02.003

[3] Kravitz LR. Developing a lifelong resistance training program. ACSM's Health & Fitness Journal. 2019;23(1):9-15

[4] Argiles JM, Campos N, Lopez-Pedrosa JM, Rueda R, Rodriquez-Manas L. Skeletal muscle regulates metabolism via interorgan crosstalk: roles in health and disease. JAMDA. 2016;17:789-796. DOI: 10.1016/j.jamda.2016.04.019

[5] Mrowka R. Westphal A. Skeletal muscle in the fight for chronic diseases. Acta Physiologica. 2018;223:e13086. DOI: 10.1111/alpha. 13086

[6] Mohamed AA, Alawna M. Role of increasing the aerobic capacity on improving the function of immune and respiratory systems in patients with coronavirus (COVID-19): A review. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. 2020;14:489-496. DOI: 10.1016/j.dsx.2020.04.038.

[7] LaVoy ECP, Fagundes CP, Dantzer R. Exercise, inflammation, and fatigue in cancer survivors. Exerc Immunol Review. 2016;22:82-93.

[8] Simpson RJ, Campbell JP, Gleeson M, Kruger K, Nieman DC, Pyne DB, Turner JE, Walsh NP. Can exercise affect immune function to increase susceptibility to infection? Exerc Immunol Review. 2020;26:8-22.

[9] Nieman DC, Wentz LM. The compelling link between physical activity and the body's defense system. J Sport Health Sci. 2019;8:201-217. DOI: 10.1016/j.jshs.2018.09.009.

[10] Mesinovic J, Zengin A, DeCourten B, Ebling PR, Scott D. Sarcopenia and Type 2 diabetes mellitus: a bidirectional relationship. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy. 2019;12:1057-1072.

[11] Lu Y, Niti M, Yap KB, Tan CTY, Nyunt MSZ, Feng L, Tan BY, Chan G, Khoo SH, Chan SM, Yap P, Larbi A, Ng TP. Assessment of sarcopenia among community-dwelling at risk frail adults aged 65 years and older who received multidomain lifestyle interventions: A secondary analysis of a randomized clinical trial. JAMA Network Open. 2019;2(10):e1913346. DOI: 10.1001/jamanetworkopen.2019.13346.

[12] Machado KLLL. Domiciano DS, Machado LG, Lopes JB, Figueiredo CP, Caparbo VF, Takayama L, Menezes PR, Pereira RMR. Risk factors for low muscle mass in a population-based prospective chohort of Brazilian community-dwelling older women: The Sao Paulo Aging & Health (SPAH) Study. J Clinical Densitometry. 2019. DOI: 10.1016/j.jocd.2019.05.001.

[13] Manini TM, Clark BC. Dynapenia and aging: An update. J Gerontol A Biol Sci Med Sci. 2012;67A(1):28-40. DOI: 10.1093/Gerona/glr010

[14] Abdalla PP, dos Santos Carvalho A, dos Santos AP, Venturina ACR, Alves TC, Mota J, Machado DRL. One-repetition submaximal protocol to measure knee extensors muscle strength among older adults with and without sarcopenia: a validation study. BMC Sports Science, Medicine and Rehabilitation. 2020;12:29. DOI: 10.1186/s13102-020-00178-9.

[15] Thompson CJ, Holskey TH, Wallenrod S, Simunovich S, Corn R. Effectiveness of a fall prevention exercise program on falls risk in community-dwelling older adults. Translational Journal of the ACSM. 2019;4(3):16-22.

[16] Vlietstra, Hendrickx. Exercise interventions in healthy older adults with sarcopenia: A systematic review and meta-analysis. Australasian Journal on Aging. 2018;37(3):169-183. DOI: 10.1111/ajag.12521.

[17] Tomeleri CM, Ribeiro AS, Souza MF, Schiavoni D, Schoenfeld BJ, Venturini D, Barbosa DS, Landucci K, Sardinha LB, Cyrino ES. Resistance training improves inflammatory level, lipid and glycemic profiles in obese older women: A randomized controlled trial. Experimental Gerontology. 2016;84:80-87. DOI: 10.1016/j.exger.2016.09.005.

[18] Caan BJ, Feliciano EMS, Prado CM, Alexeeff S, Kroenke CH, Bradshaw P, QuesenberryCP,WeltzienEK,CastilloAL, Olobatuyi TA, Chen WY. Association of muscle and adiposity measured by computed tomography with survival in patients with nonmetastatic breast cancer. JAMA Oncology. 2018. DOI: 10.1001/jamaoncol.2018.0137.

[19] Feliciano EMC, Kroenke CH, Meyerhardt JA, Prado CM, Bradshw PT,Kwan ML, Xiao J, Alexeff S, Corley C, Weltzien E, Castillo AL, Caan BJ. Association of systemic inflammation and sarcopenia with survival in nonmetastatic colorectal cancer: Results from the C SCANS study. JAMA Oncol. 2017;3(12):e172319. DOI: 10.1001/jamaoncol.2017.2319.

[20] Williams GR, Chen Y, Kenzik KM, McDonald A, Shachaar SS, Klepiin HD Kritchevsky S, Bhatia S. Assessment of sarcopenia measures, survival, and disability in older adults before and after diagnosis with cancer. JAMA Network Open. 2020;3(5):e204783. DOI: 10.1001/jamanetworkopen.2020.4783.

[21] Gilchrist SC, Howard VJ, Akinyemiju T, Judd SE, Cushman M, Hooker SP, Diaz KM. Association of sedentary behavior with cancer mortality in middle-aged and older US adults. JAMA Oncology. 2020;6(8):1210-1217. DOI:10.1001/jamaoncol.2020.2045.

[22] Brown JM, Shackelford DYK, Hipp ML, Hayward R. Evaluation of an exercise-based phase program as part of a standard care model for cancer survivors. Translational Journal of the ACSM. 2019;4(7):45-54.

[23] Campbell KL, Winters-Stone KM, Wiskemann J, May AM, Schwartz AL, Courneya KS, Zucker DS, Matthews CE, Ligibel JA, Gerber LH, Morris GS, Patel AV, H TF, Perna FM Schmitz KH. Exercise guidelines for cancer survivors: Consensus statement for international multidisciplinary roundtable. Medicine & Science in Sports Medicine. 2019;51(11):2375-2390. DOI: 10.1249/MSS.0000000000002116.

[24] Cheema BS, Fairman CM, Marthick M. Exercise professionals in the cancer center: Experiences, recommendations, and future research. Translational Journal of ACSM. 2019;4(1):96-105.

[25] Schmitz KH, Campbell AM, Stuiver MM, Pinto BM, Swhwartz AL, Morris GS, Ligibel JA, Cheville A, Galvao DA, Alfno CM, Patel AV, Hue T, Gerber LH, Sallis, R, Gusani NJ, Stout NL, Chan L, Flowers F, Doyle C, Hemmrich S, Bain W, Sokolof J, WintersStone, KM, Campbell KL, Matthews CE. Exercise is medicine in oncology: Engaging clinicians to help patients move through cancer. CA Cancer J Clin. 2019;0:1-17.

[26] Patel AV, Friedenreich CM, Moore SC, Hayes SC, Silver JK, Campbell KL, Winters-stone K, Gerber LH, George SM, Fulton JE,

Denlinger C, Morris GS, Hue T, Schmitz KH, Matthews CE. American College of Sports Medicine roundtable report on physical activity, sedentary behavior, and cancer prevention and control. Med Sci Sports Exerc. 2019;51(11):2391-2402. DOI: 10.1249/MSS0000000000002117.

[27] Mctiernan A, Friedenreich CM, Katzmarzyk PT, Powell KE, Macko R, Buchner D, Pescatello LS, Bloodgood B, Tennant B, Vaux-Bjerke A, George SM, Troiano RP, Piercy KL. Physical activity in cancer prevention and survival: A systemic review. Med Sci Sports Exerc. 2019;51(6):1252-1261. DOI: 10.1249/MSS.0000000000001937.

[28] Haran PA, Rivas DA. Role and potential mechanisms of anabolic resistance in sarcopenia. J Cachexia Sarcopenia Muscle. 2012;3:157-162. DOI: 10.1007/s13539-012-0068-4.

[29] Garcia-HermosoA,Cavero-RedondoI, Ramirez-Valez R, Ruiz JR, Ortega FB, Lee DC, Martinez-Vizcaino V. Muscular strength as a predictor of all-cause mortality in an apparently healthy population: A systematic review and meta-analysis of data from approximately 2 million men and women. Archives of Physical Medicine and Rehabilitation. 2018;99:2100-2113. DOI: 10.1016/j.apmr.2018.01.008.

[30] Moberg M, Lindholm ME, Reitzner SM, Ekblom B, Sundberg CJ, Psilander N. Exercise induces different molecular responses in trained and untrained human muscle. Med Sci Sports Exerc. 2020;52(8):1679-1690. DOI: 10.1249/MSS.0000000000002310.

[31] Abramowitz MK, Hall CB, Amodu A, Sharma D, Androga L, Hawkins M. Muscle mass, BMI, and mortality among adults in the United States: A population-based cohort study. PLOS One. 2018. DOI: 10.1371/journal.pone.0194697.

[32] Churchward-Venne TA, Tieland M, Verdijk LB, Leenders M, Dirks ML, DeGroot LCPGM. There are no nonresponders to resistance-type exercise training in older men and women. JAMDA. 2015;16:400-411. DOI: 10.1016/j.jamda.2015.01.071.

[33] Dai X, Zhai L, Chen Q, Miller JD, Lu L, Hsue C, Lie L, Yuan X, Wei W, Ma X, Fang Z, Zhao W, Lie Y, Huang F, Lou Q. Two-year-supervised resistance training prevented diabetes incidence in people with prediabetes: A randomized control trial. Diabetes Metab Res Rev. 2019;35:e3143. DOI: 10.1002/dmmr.3143.

[34] Beaumont C, Ferrara PMM, Strohacker K. Measurements of acute affective responses to resistance training exercise: A narrative review. Translational Journal of the ACSM. 2020;5(11):1-7.

[35] Church TS, Thomas DM, Tudor-Locke C, Katzmarzyk PT, Earnest CP, Rodarte RQ, Martin CK, Blair SN, Bouchard C. Trends over 5 decades in U.S. occupation-related physical activity and their associations with obesity. PLOS One. 2011;6(5):e19657. DOI. 10.1371/journal.pone.0019657.

[36] Brighenti-Zoag S, Mundwiler J, Schupbach U, Dieterie T, Wolfer DP, Leuppi JD, Miedinger D. Physical workload and work capacity across occupational groups. PLOS One. 2016. DOI: 10.1371/journal.pone.0154073.

[37] Industrial Physical Capability Services, Inc. (IPCS). Available from http://www.ipcs-inc.com.

[38] Biodex. 2020. Biodex System 4 Pro™ [Apparatus and software]. Available from http://www.biodex/physical-medicine/products/dynamometers/system-4-pro.

[39] Ostbye T, Dement JM, Krause KM. Obesity and workers compensation. Arch Intern Med. 2007;167:766-773.

[40] Terpeluk P, Rogen B, Gilliam T. Medical and pharmacy costs for new hire nurses following a physical strength evaluation screening in a large health system. Workplace Health & Safety. 2016;64(9):420-425. DOI: 10.1177/2165079915621317.

[41] Dictionary of Occupational Titles Appendix C: Components of the definition trailer. 2015. Retrieved from http://www.lb7.uscourts.gov/documents/11c2448.pdf.