

Supplementary Materials: Evaluating Metrics for Comparing Powerlifters

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Table 1: Scores for Classifications of IPF Lifters (From IPF Sample, n = 66,374)

Lifter Classification	Elite	Master	Class 1	Class 2	Class 3	Class 4	Class 5	Novice
Quantile	.975	.95	.85	.75	.5	.25	.1	0
Wilks	515.49	487.99	429.52	400.27	349.88	301.90	259.16	< 259.16
Updated Wilks	724.41	680.88	603.36	561.95	493.47	431.15	375.66	< 375.66
DOTS	517.84	489.85	431.46	402.17	351.83	303.54	260.58	< 260.58
Goodlift	94.10	90.04	82.57	77.93	68.98	59.73	51.07	< 51.07
P5	409.73	390.78	356.88	337.48	300.34	263.65	228.46	< 228.46
P2	409.87	390.91	356.93	337.51	300.44	263.42	228.35	< 228.35
P2SPL	409.71	390.59	356.92	337.42	300.35	263.65	228.45	< 228.44

Figure 1: Average Bias by Male Weight Class, Lifter Classification for 10,000 Bootstrap Samples

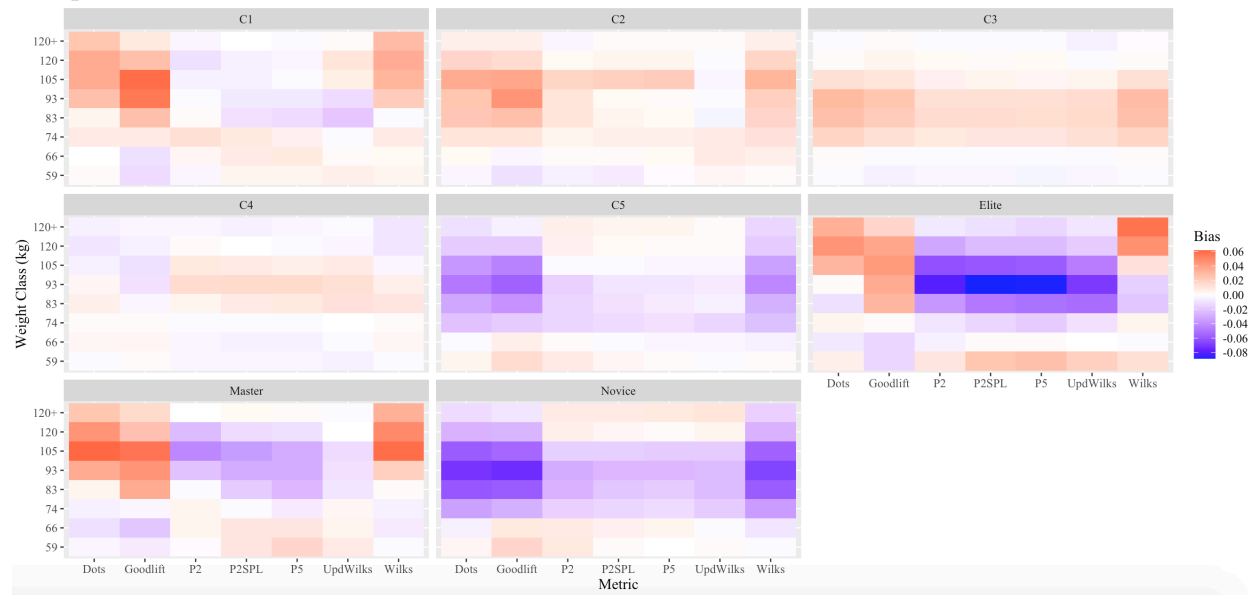


Figure 2: Average Bias by Female Weight Class, Lifter Classification for 10,000 Bootstrap Samples

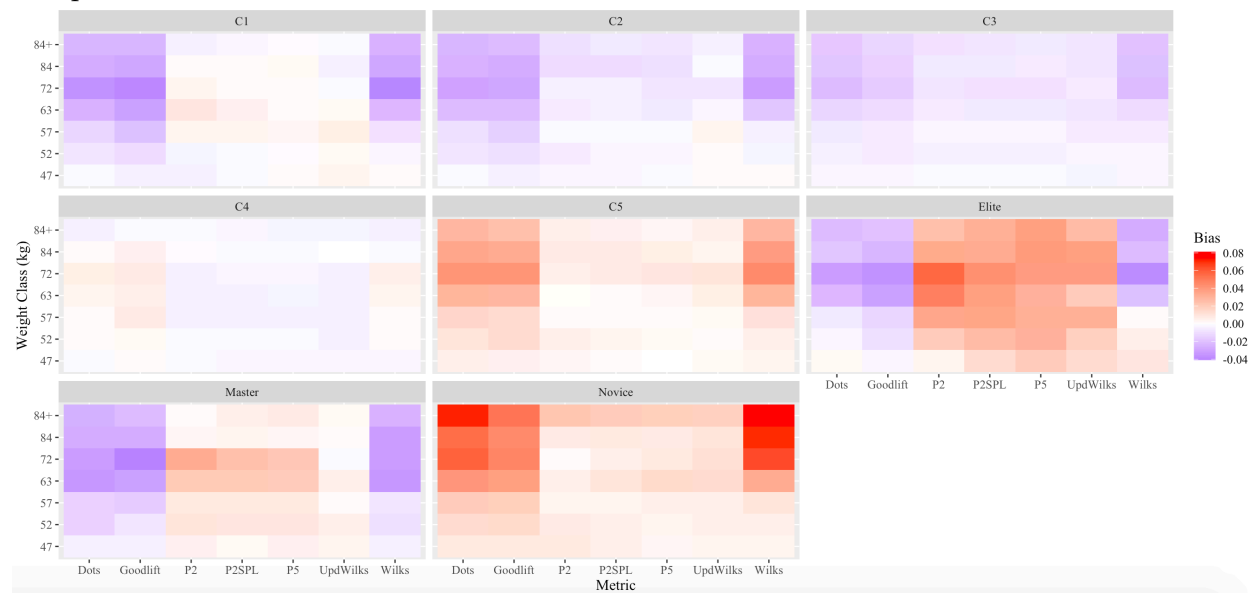


Figure 3: Average Bias by Sex, Lifter Classification for 10,000 Bootstrap Samples

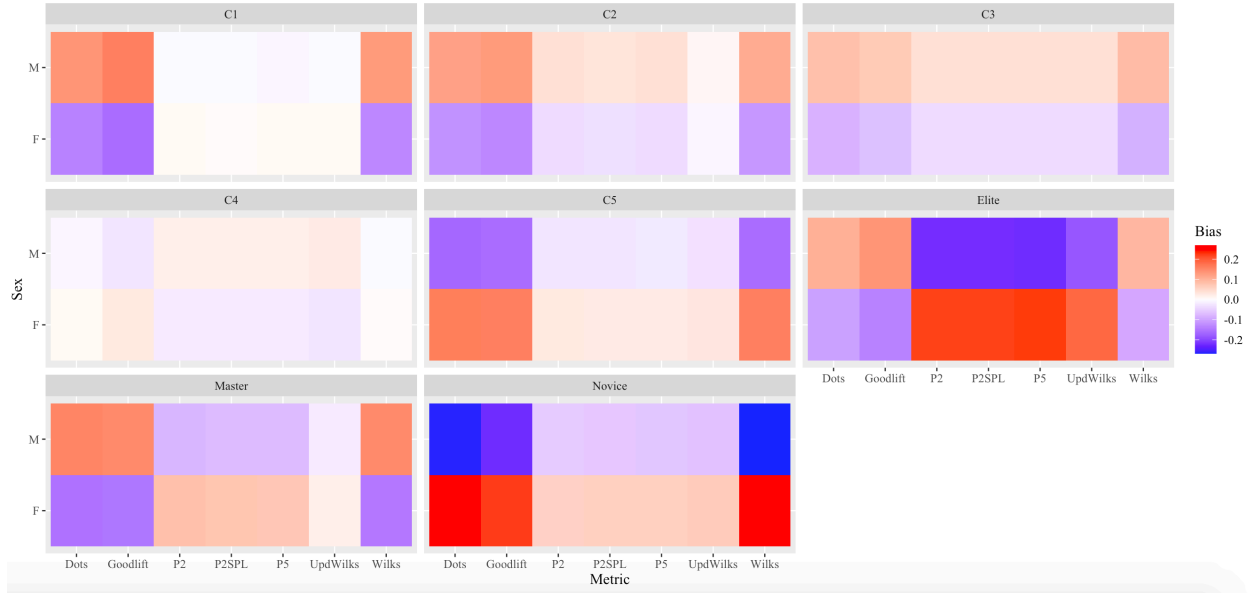
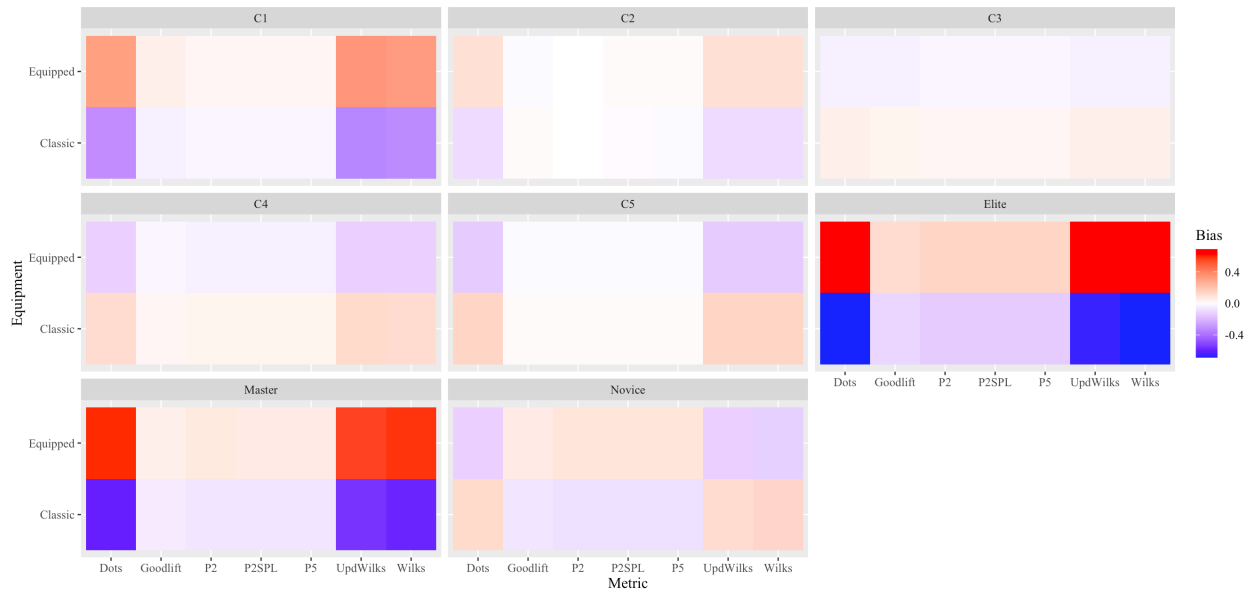


Figure 4: Average Bias by Equipment, Lifter Classification for 10,000 Bootstrap Samples



1 Relative Distance to World Record: 2019 IPF World Championships

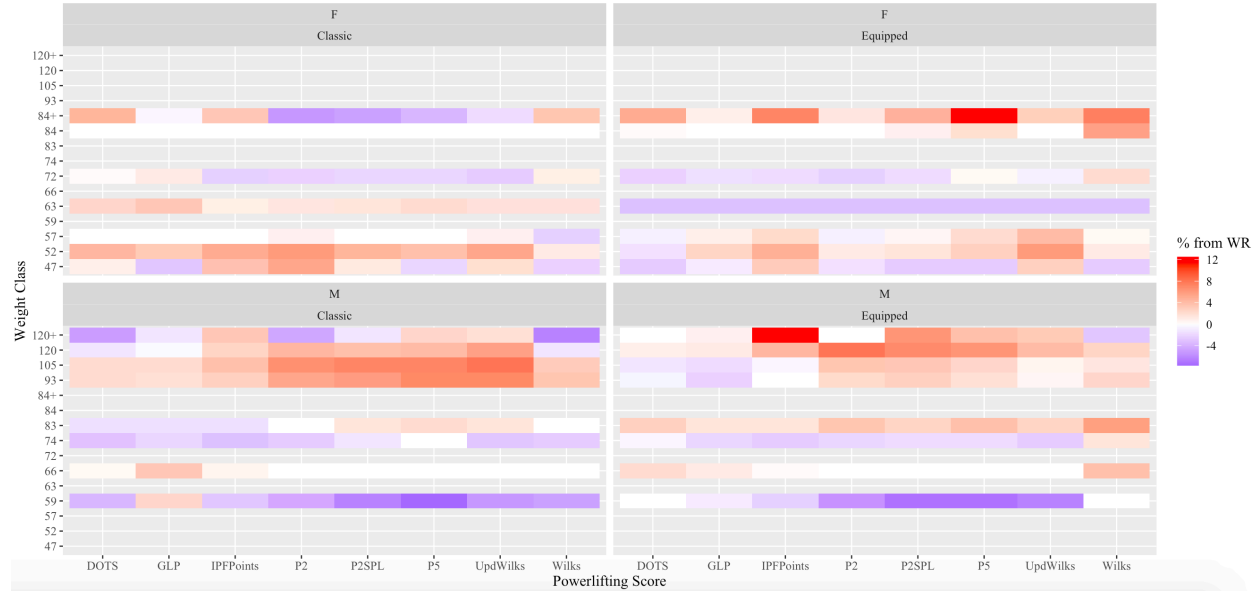
Prior to discussing the replication of Konertz’s analysis, it is important to assert what the criteria of evaluation are. These truly depend on the standard to which the IPF holds for its lifters, as well as the consistency of that standard across sex and equipment divisions. In order to win the best lifter award at the IPF World Championships, a lifter should break a world record. This should be the minimum standard for best lifter, regardless of the weight class and margin by which a record should be set. Breaking a world record would be characterized by a positive relative difference (greater than 0%) from the previous record. Another stipulation is that the standard for winning best lifter should be higher than that for placing top 3 within the same sex/equipment division. A higher standard for best lifter could mean either breaking a world record to win best lifter and not breaking a record to place top 3, or simply breaking a record by a larger margin to win best lifter compared to placing top 3. Considering that multiple world records were broken within each division at the classic and equipped 2019 IPF World Championships, it is reasonable for the standard for placing in the top 3 should be coming very close to or breaking a world record in a given weight class. To build on the standard of placing in the top 3, this would mean that the best lifter should break the world record in his/her weight class with an exemplary relative performance. This would come in the form of breaking the world record by margin of at least 2 to 3%. This seems to be a consensus from the results obtained in the evaluation of the 2019 IPF World Championships. For each sex/equipment division, relative distance from the world record to place top 3 and win best lifter was calculated. Heatmaps in Figures 5 and 6 display these relative differences to win best lifter and place top 3, respectively, for the four divisions by weight class. Table 2 shows the mean relative differences from the world record for each powerlifting score, while Table 3 displays mean relative distance from WR by powerlifting score and division. A positive relative distance indicated breaking a world record by n% to win or place top 3, while a negative score indicated the ability to win or place top 3 despite falling n% short of the world record. Across the four divisions, powerlifting scores had standards of 3 to 7% above the world record, on average, to be considered best lifter (Table 2). The lowest standards were those of GLP (2.92%), DOTS (3.14%), and Wilks (3.60%). The highest average standards for best lifter came from novel scores, Updated Wilks, and IPF Points, ranging from 5.29-6.7% above the world record. To place in the top 3 lifters within a division, DOTS (.035%) and GLP (.189%) had mean relative distances (MRD) just above the world record, while P2 (.542%), Wilks (.666%), and P2SPL (.791%) required slightly better average performances. Updated Wilks, IPF Points, and P5 all had mean relative distances above 1% for lifters to place in the top 3. It is also important to evaluate these record distances by individual division and by weight class.

When looking at the mean relative distance (MRD) required to win best lifter and place top 3 at the 2019 IPF World Championships, standards differed by division for most powerlifting scores. In Table 3, the two scores with the lowest average standards, GLP and DOTS exhibited similar behavior. Winning best lifter in women’s equipped required stronger performance on average than any other division, while men’s equipped required the lowest MRD of all divisions. The divisions with the second and third highest standards by DOTS for best

lifter, respectively, were women's classic then men's classic. GLP had approximately the same standard for best lifter in men's classic (2.70% MRD) than women's classic (2.65% MRD). Wilks had similar standards as DOTS and GLP for 3 divisions, but had a much higher MRD for men's equipped lifters (4.92% compared to 1.03% and 1.36%, respectively). All other scores had noticeably higher standards for winning best lifter. The score outside of GLP and DOTS with the least variable standards for best lifter was P2, with a standard error of 0.81%. Still, GLP and DOTS seemed to have the most realistic standards for best lifter. GLP seemed to be less variable in its best lifter standard than DOTS, with a standard error for MRD of 0.81% compared to 1.16%. Similar results are observed in the standards for placing within the top 3. Most scores required that lifters in 2 or more of the 4 divisions needed total over 1% more than the world record to place in the top 3. A standard of more than 1% above the world record seems high for placing top 3, as it should be closer to 0% which would reflect tying a world record. Three scores were able to more closely reflect this standard: DOTS, GLP, and P2. The least variable in its standard for top 3 was GLP with a standard error for MRD of 0.27%, followed by P2 (0.42%), then DOTS (0.67%). GLP's average standards for placing top 3 were a fraction of a percent below the world record for men's (-0.305%) and women's equipped (-0.209%), while slightly above the world record for women's classic (0.654%) and men's classic (0.624%). P2 had its lowest mean standard for placing top 3 in the women's equipped division (-0.709%), while requiring breaking world records for all other divisions. DOTS' standards for men's and women's equipped were both close to the world record, but noticeably higher for women's classic (1.76%) and lower for men's classic (-1.28%).

From a weight class perspective, the relative distance from world record to place in the top 3 and win best lifter from the 2019 IPF World Championships can provide a granular look at standards for powerlifting scores. Figures 5 and 6 in the supplementary materials provide a visual and unaggregated representation of the MRD results from Tables 2 and 3. For the four separate divisions, standards for placing top 3 should be around 0% (near the WR). This would be represented by white or a lighter red or blue in Figure 5. The standards for best lifter should ideally be somewhere around 1-2% as previously mentioned, breaking the WR by a slight margin. The lower positive standard, generally the better. This would be visualized as a lighter red in Figure 6. Ideally, a powerlifting score would show similar distribution of these desired colors in both Figures 5 and 6 if its standards are consistent and fair. For placing top 3 (Figure 5), scores that met these specifications differ by division. DOTS and GLP both displayed the most uniform standards for placing top 3 the male equipped division. The relative distance from world record for top 3 was most evenly distributed by GLP, followed by IPF Points which had higher standards for heavy lifters, and DOTS which had low standards for heavyweights. Both female divisions had more candidate scores with uniform and fair relative distances from the WR. DOTS, GLP, Updated Wilks, and Wilks all held ideal standards for the female classic division. DOTS, GLP, P2, and P2SPL were ideal for top 3 standards for female equipped lifters. The clear best performers for top 3 standards were DOTS and GLP, providing arguably the most balance and precision of all scores considered. Similarly, standards for best lifter were best met by DOTS and GLP given the consistency of standard of slightly surpassing world records for across all weight classes in each division. However, GLP visually looked to be more uniform in its standards across weight classes. GLP had no weight classes that were held

Figure 5: Relative Distance from WR to Place Top 3 Overall, IPF World Championships 2019



to noticeably different standards. DOTS had a standard for 120+ kg classic men that was below the world record, which is unideal. In the women's equipped division, 84+ kg women were held to a significantly higher standard than all other weight classes. The consistency of standard across weight classes and divisions makes GLP the best score currently available for ranking powerlifters at the Elite level. It performed better than DOTS in its goodness-of-fit for all lifter classifications in bootstrap samples and at the Elite level when evaluating standards of placings at the 2019 IPF World Championships. Thus, the IPF should continue to use GLP to compare Elite lifters at high-level national competitions such as USAPL Raw Nationals and the IPF World Championships.

Figure 6: Relative Distance from WR to Win Best Lifter, IPF World Championships 2019

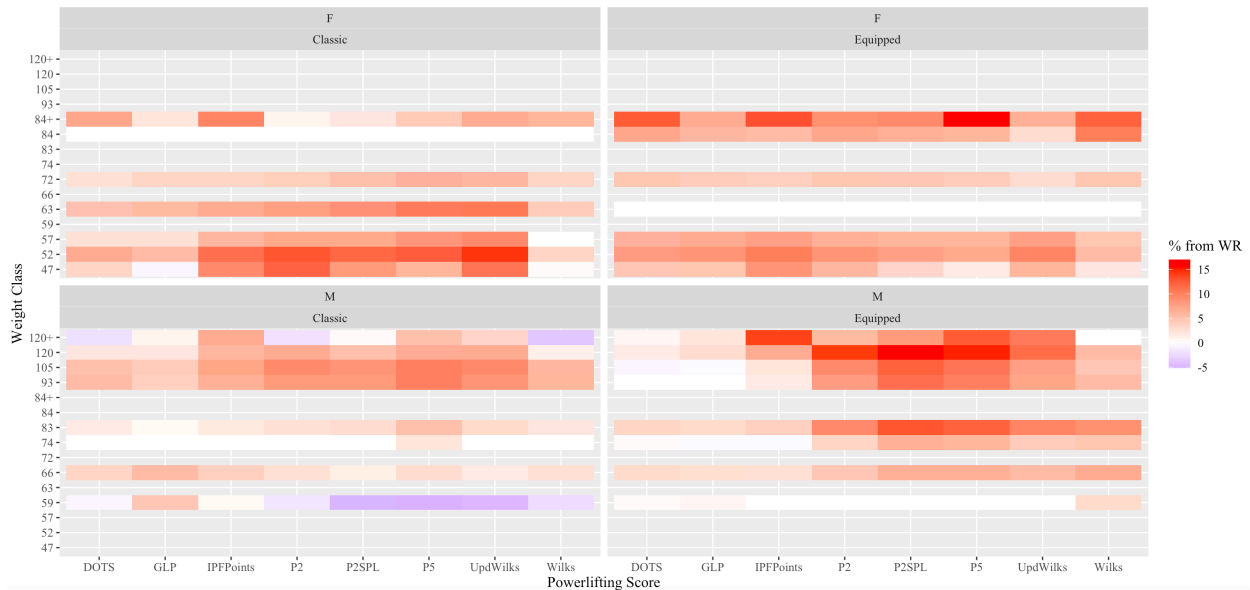


Table 2: Mean Relative Distance from IPF World Record to Achieve Best Lifter, Top 3 at 2019 IPF World Championships

Score Name	MRD Above WR to Achieve Best Lifter	MRD Above WR to Achieve Top 3
DOTS	3.14%	.035 %
GLP	2.92%	.189 %
Wilks	3.60%	0.666 %
Upd. Wilks	5.95%	1.19 %
IPF Points	5.29%	1.37 %
P5	6.70%	1.22 %
P2	5.59%	0.542 %
P2SPL	5.84%	0.791 %

Table 3: Mean Relative Distance by Score and Division from IPF World Record to Achieve Best Lifter, Top 3 at 2019 IPF World Championships

Score Name	Division	MRD Above WR to Achieve Best Lifter	MRD Above WR to Achieve Top 3
DOTS	Women's Classic	3.92%	1.76 %
	Women's Equipped	6.23%	-0.676 %
	Men's Classic	1.86%	-1.28 %
	Men's Equipped	1.03%	0.462%
GLP	Women's Classic	2.65%	0.654 %
	Women's Equipped	5.25%	-0.209 %
	Men's Classic	2.70%	0.624 %
	Men's Equipped	1.36%	-0.305 %
Wilks	Women's Classic	2.50%	0.394 %
	Women's Equipped	5.65%	1.54 %
	Men's Classic	1.43%	-1.04 %
	Men's Equipped	4.92%	1.85 %
Upd. Wilks	Women's Classic	8.32%	0.76 %
	Women's Equipped	5.13%	1.73 %
	Men's Classic	3.49%	2.02 %
	Men's Equipped	7.06%	0.259 %
IPF Points	Women's Classic	6.67%	0.76 %
	Women's Equipped	6.99%	1.77 %
	Men's Classic	4.06%	0.702 %
	Men's Equipped	3.82%	1.52 %
P5	Women's Classic	6.90%	-0.253 %
	Women's Equipped	6.01%	2.01 %
	Men's Classic	4.62%	1.92 %
	Men's Equipped	9.21%	1.12 %
P2	Women's Classic	6.36%	0.899 %
	Women's Equipped	5.97%	-0.709 %
	Men's Classic	3.26%	0.628 %
	Men's Equipped	6.90%	1.24 %
P2SPL	Women's Classic	6.15%	0.0886 %
	Women's Equipped	5.34%	0.0157 %
	Men's Classic	2.68%	1.23 %
	Men's Equipped	9.18%	1.64 %