**Supplementary Table S1.** Detection performance of 5 methods on the simulated datasets with light skewness, under $k_l = k_r = 1$.

| Method | TP | FP | FN | TN | Sensitivity | Specificity | Misclassification | Balanced Accuracy |
|---|---|---|---|---|---|---|---|---|
| DTOD | 6.39 | 6.16 | 3.61 | 193.84 | 63.88% | 96.92% | 4.65% | 80.41% |
| Modified Z-score | 5.27 | 8.20 | 4.73 | 191.80 | 52.67% | 95.90% | 6.16% | 74.30% |
| IQR | 5.80 | 2.47 | 4.20 | 197.53 | 58.00% | 98.77% | 3.17% | 78.38% |
| Z-score | 0.13 | 0.20 | 9.87 | 199.80 | 1.33% | 99.90% | 4.79% | 50.60% |
| kNN | 0.40 | 0.60 | 9.60 | 199.40 | 4.00% | 99.70% | 4.86% | 51.85% |

**Supplementary Table S2.** Detection performance of 5 methods on the simulated datasets with middle skewness, under $k_l = k_r = 1$.

| Method | TP | FP | FN | TN | Sensitivity | Specificity | Misclassification | Balanced Accuracy |
|---|---|---|---|---|---|---|---|---|
| DTOD | 1.95 | 1.85 | 8.05 | 198.15 | 19.49% | 99.08% | 4.71% | 59.29% |
| Modified Z-score | 6.33 | 4.67 | 3.67 | 195.33 | 63.33% | 97.67% | 3.97% | 80.48% |
| IQR | 6.33 | 4.67 | 3.67 | 195.33 | 63.33% | 97.67% | 3.97% | 80.48% |
| Z-score | 1.80 | 0.67 | 8.20 | 199.33 | 18.00% | 99.67% | 4.22% | 58.83% |
| kNN | 0.33 | 0.67 | 9.67 | 199.33 | 3.33% | 99.67% | 4.92% | 51.48% |

**Supplementary Table S3.** Detection performance of 5 methods on the simulated datasets with high skewness, under $k_l = k_r = 1$.

| Method | TP | FP | FN | TN | Sensitivity | Specificity | Misclassification | Balanced Accuracy |
|---|---|---|---|---|---|---|---|---|
| DTOD | 2.68 | 0.27 | 7.32 | 199.73 | 26.79% | 99.86% | 3.62% | 63.33% |
| Modified Z-score | 5.53 | 52.47 | 4.47 | 147.53 | 55.33% | 73.77% | 27.11% | 64.53% |
| IQR | 4.40 | 22.80 | 5.60 | 177.20 | 44.00% | 88.60% | 13.52% | 66.30% |
| Z-score | 3.87 | 2.47 | 6.13 | 197.53 | 38.67% | 98.77% | 4.10% | 68.73% |
| kNN | 0.07 | 0.93 | 9.93 | 199.07 | 0.67% | 99.53% | 5.17% | 50.12% |

**Supplementary Table S3.** Detection performance of 5 methods on the simulated datasets with light skewness, under $k_l = 0.6,\ k_r = 1.07$.

| Method | TP | FP | FN | TN | Sensitivity | Specificity | Misclassification | Balanced Accuracy |
|---|---|---|---|---|---|---|---|---|
| DTOD | 8.66 | 7.19 | 1.35 | 192.81 | 86.55% | 96.40% | 4.07% | 91.46% |
| Modified Z-score | 1.93 | 0.21 | 8.07 | 199.79 | 19.29% | 99.89% | 3.95% | 59.60% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| IQR | 8.21 | 2.21 | 1.79 | 197.79 | 82.14% | 98.89% | 1.90% | 90.50% |
| Z-score | 0.14 | 0.07 | 9.86 | 199.93 | 1.43% | 99.96% | 4.73% | 50.68% |
| kNN | light | 0.93 | 0.07 | 9.07 | 199.93 | 9.29% | 99.96% | 4.35% |

**Supplementary Table S4.** Detection performance of 5 methods on the simulated datasets with middle skewness, under $k_l = 0.6,\ k_r = 1.07$.

| Method | TP | FP | FN | TN | Sensitivity | Specificity | Misclassification | Balanced Accuracy |
|---|---|---|---|---|---|---|---|---|
| DTOD | 5.05 | 3.90 | 4.95 | 196.10 | 50.47% | 98.05% | 4.22% | 74.28% |
| Modified Z-score | 5.53 | 4.40 | 4.47 | 195.60 | 55.33% | 97.80% | 4.22% | 76.55% |
| IQR | 5.67 | 4.87 | 4.33 | 195.13 | 56.67% | 97.57% | 4.38% | 77.13% |
| Z-score | 3.07 | 0.80 | 6.93 | 199.20 | 30.67% | 99.60% | 3.68% | 65.15% |
| kNN | 0.67 | 0.33 | 9.33 | 199.67 | 6.67% | 99.83% | 4.60% | 53.27% |

**Supplementary Table S5.** Detection performance of 5 methods on the simulated datasets with high skewness, under $k_l = 0.6,\ k_r = 1.07$.

| Method | TP | FP | FN | TN | Sensitivity | Specificity | Misclassification | Balanced Accuracy |
|---|---|---|---|---|---|---|---|---|
| DTOD | 3.01 | 0.32 | 6.99 | 199.68 | 30.14% | 99.84% | 3.48% | 64.97% |
| Modified Z-score | 5.53 | 52.47 | 4.47 | 147.53 | 55.33% | 73.77% | 27.11% | 64.53% |
| IQR | 4.40 | 22.80 | 5.60 | 177.20 | 44.00% | 88.60% | 13.52% | 66.30% |
| Z-score | 3.87 | 2.47 | 6.13 | 197.53 | 38.67% | 98.77% | 4.10% | 68.73% |
| kNN | 0.53 | 0.47 | 9.47 | 199.53 | 5.33% | 99.77% | 4.73% | 52.53% |

**Supplementary Table S6.** Detection performance of 5 methods on the simulated datasets with light skewness, under $k_l = 0.4,\ k_r = 1.2$.

| Method | TP | FP | FN | TN | Sensitivity | Specificity | Misclassification | Balanced Accuracy |
|---|---|---|---|---|---|---|---|---|
| DTOD | 9.96 | 5.30 | 0.04 | 194.70 | 99.59% | 97.35% | 2.54% | 98.48% |
| Modified Z-score | 2.09 | 0.09 | 7.91 | 199.91 | 20.91% | 99.95% | 3.81% | 60.43% |
| IQR | 9.09 | 2.00 | 0.91 | 198.00 | 90.91% | 99.00% | 1.39% | 94.95% |
| Z-score | 3.73 | 0.09 | 6.27 | 199.91 | 37.27% | 99.95% | 3.03% | 68.63% |
| kNN | 0.91 | 0.09 | 9.09 | 199.91 | 9.09% | 99.95% | 4.37% | 54.53% |

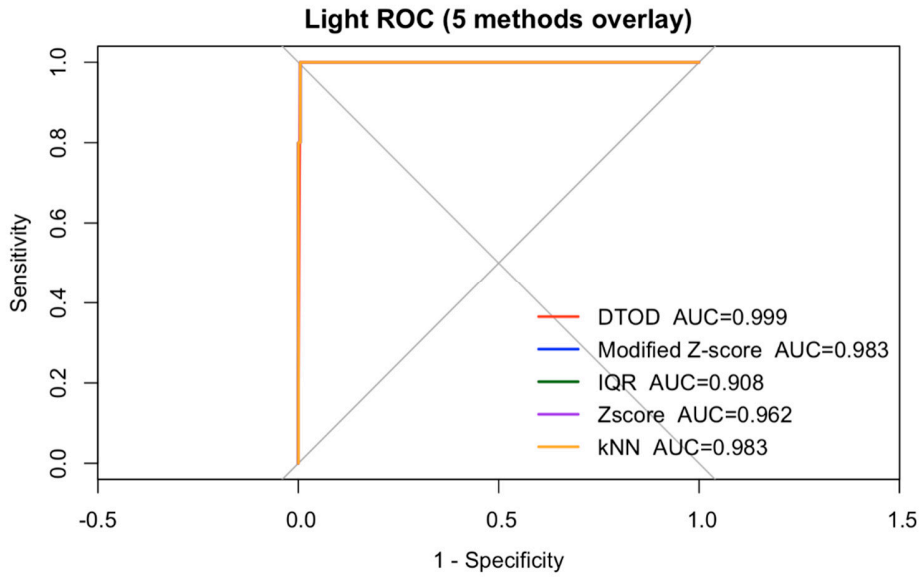
**Supplementary Table S7.** Detection performance of 5 methods on the simulated datasets with middle skewness, under $k_l = 0.4,\ k_r = 1.2$.

| Method | TP | FP | FN | TN | Sensitivity | Specificity | Misclassification | Balanced Accuracy |
|---|---|---|---|---|---|---|---|---|
| DTOD | 3.47 | 1.00 | 6.53 | 199.00 | 34.69% | 99.50% | 3.59% | 67.10% |
| Modified Z-score | 7.00 | 4.07 | 3.00 | 195.93 | 70.00% | 97.97% | 3.37% | 83.98% |
| IQR | 7.00 | 4.27 | 3.00 | 195.73 | 70.00% | 97.87% | 3.46% | 83.93% |
| Z score | 4.67 | 0.27 | 5.33 | 199.73 | 46.67% | 99.87% | 2.67% | 73.28% |
| kNN | 0.67 | 0.33 | 9.33 | 199.67 | 6.67% | 99.83% | 4.60% | 53.27% |

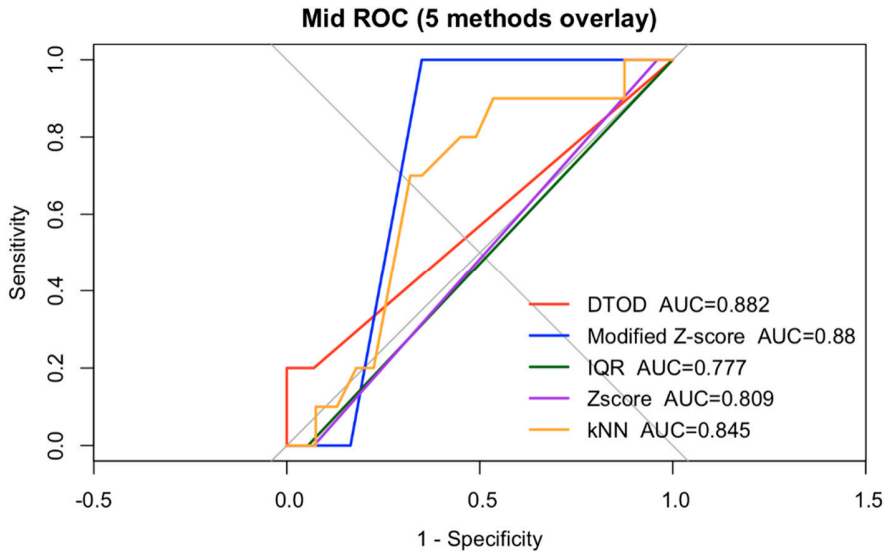
**Supplementary Table S8.** Detection performance of 5 methods on the simulated datasets with high skewness, under $k_l = 0.4,\ k_r = 1.2$.

| Method | TP | FP | FN | TN | Sensitivity | Specificity | Misclassification | Balanced Accuracy |
|---|---|---|---|---|---|---|---|---|
| DTOD | 2.05 | 0.08 | 7.95 | 199.92 | 20.46% | 99.96% | 3.82% | 60.23% |
| Modified Z-score | 7.53 | 50.73 | 2.47 | 149.27 | 75.33% | 74.63% | 25.33% | 74.97% |
| IQR | 6.47 | 21.13 | 3.53 | 178.87 | 64.67% | 89.43% | 11.75% | 77.07% |
| Z score | 5.27 | 2.13 | 4.73 | 197.87 | 52.67% | 98.93% | 3.27% | 75.82% |
| kNN | 0.80 | 0.20 | 9.20 | 199.80 | 8.00% | 99.90% | 4.48% | 53.95% |

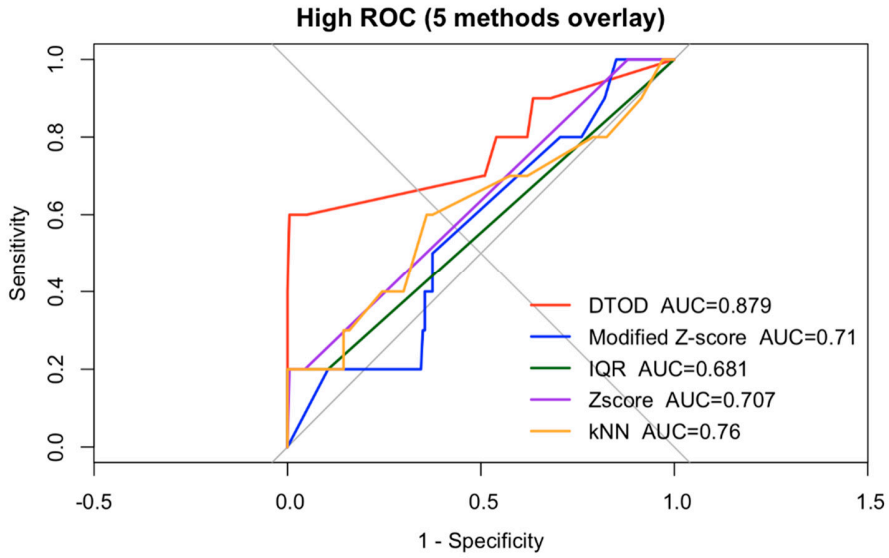
**Supplementary Figure S1.** Mean ROC curves for five outlier detection methods under light skewness



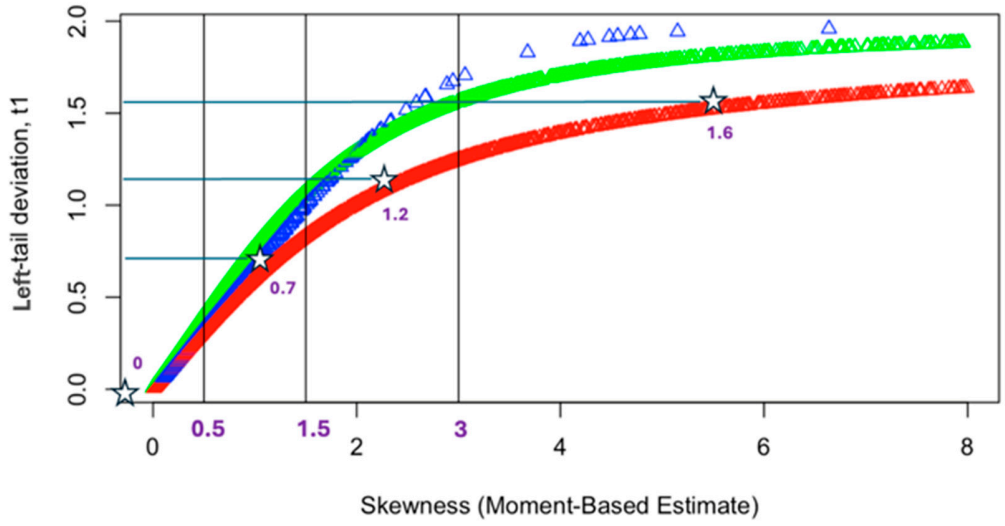
**Supplementary Figure S2.** Mean ROC curves for five outlier detection methods under medium skewness




**Supplementary Figure S3.** Mean ROC curves for five outlier detection methods under high skewness



**Supplementary Figure S4.** Left-tail adjustment ($t_1$) based on skewness levels. Red represents Log-normal distribution, blue represents Gamma distribution and green represents Weibull distribution.




**Supplementary Figure S5.** Right-tail adjustment ($t_2$) based on skewness levels. Red represents Log-normal distribution, blue represents Gamma distribution and green represents Weibull distribution.

